CORROSION CONTROL OPTIONS FOR THE U.S. MARINE CORPS LOGISTICS VEHICLE SYSTEM (LVS)

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14. ABSTRACT
The purpose of this analysis was to determine and document the extent of corrosion problems on the LVS, determine the cause of the corrosion, and make specific recommendations to alleviate the cause of the corrosion problems. The study consisted of a visual inspection, literature searches, corrosion control assessment, a performance cost comparison, and a written investigative analysis.

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ADMINISTRATIVE

This report presents the results of a corrosion characterization, literature review, corrosion assessment, and performance based specification for improved corrosion control on the U.S. Marine Corps LVS. This report was prepared for NSWCCD (Code 28) CASDE Corporation, a wholly owned subsidiary of DDLOMNI Engineering, under Contract N00167-93-D-0054, Delivery Order 0013.

CORROSION CONTROL OPTIONS FOR THE LVS

I. EXECUTIVE SUMMARY

1.0 INTRODUCTION. In light of the contractual LVSA1 corrosion prevention measures between the Marine Corps and Oshkosh Trucking Corporation, it was decided that this analysis would evaluate the LVSA1 measures, and provide alternative measures with cost comparisons. This analysis will also recommend additional government corrosion control testing and corrosion control tests that may be included in the LVSR Advanced Technology Demonstrator program. To this end, specific components, causes of corrosion and proposed LVSA1 options were identified. The following paragraphs summarize the results of the evaluations performed, and are reported herein on corrosion control options for the LVSR.

2.0 BODY AND CHASSIS COMPONENTS. The following LVS body and chassis components were reported to be susceptible to corrosion induced failures and were identified as requiring corrosion control improvements for the LVSR system.

2.1 <u>CAR DOORS</u>.

LVSA1 Recommendations: OTC will utilize a three part corrosion control technology consisting of hot dip galvanneal sheet steel (60-67 gms/sq.m.) followed by a zinc phosphate conversion coating and application of a final E-coat.

Recommendations for LVSR: Galvanneal is a zinc-iron alloy coating that provides better corrosion resistance, weldability and top coat adherence than hot dip galvanized (HDG) coatings. This corrosion control technology is used in the U.S. automotive industry. A zinc rich layer below the E-coat protects the steel in case the E-coat barrier is breached. In this connection, Galvanneal provides more sacrificial protection to steel than HDG.

2.2 CAB.

LVSA1 Recommendations: This component will receive an E-coat and undercoat/ rustproofing on the LVSA1. Drain holes, 0.5" diameter, have been added to prevent water build up in the bottom of the structure. OTC has reported difficulty in plug welding HDG portions of the cab weldment to the outer skins.

Recommendations for LVSR: Based on this issue, it is recommended that a zinc-silicate primer followed by application of a zinc phosphate conversion coating be applied prior to the proposed E-coat for the LVSR cab.

2.3 FENDERS.

LVSA1 Recommendations: OTC will use galvanneal steel followed by E-coat and rustproof/undercoated in the wheel wells on the LVSA1.

Recommendations for LVSR: This appears to be the appropriate corrosion control option for this application.

2.4 CARGO BODY AND DROPSIDES.

LVSA1 Recommendations: This component will be E-coated and rustproofed/undercoated on the LVSA1. This application takes significant abuse. Therefore, it is not expected that E-coat, even with a zinc phosphate conversion under-coating, will have a long service life.

Recommendations for LVSR: It is recommended that this application be manufactured using HDG steel (1.7 mils) followed by phosphatizing and E-coat for the LVSR. As a longer term option, fabrication of this application using pultruded fiberglass composite structure is well within the state of the art.

2.5 RADIATOR GRILLE/GRATE ASSEMBLY.

LVSA1 Recommendations: OTC will E-Coat the radiator grille and will use a 9 gauge galvanneal steel (followed by phosphate conversion coating and paint) for the grate.

Recommendations for LVSR: These improvements appear appropriate and should be effective.

2.6 TOOL BOXES.

LVSA1 Recommendations: The LVSA1 toolboxes will be E-coated and the bottom exterior of the box will be undercoated. Due to the damage from impact of tools, the E-coat is expected to fail and result in corrosion of the steel substrate.

Recommendations for LVSR: Aluminum thermal spray technology has been undergoing evaluation by the USMC and should provide a durable and corrosion-resistant tool box.

2.7 BRACKETS, STEPS, STRUTS, SUPPORTS AND FUEL TANK STRAPS.

LVSA1 Recommendations: E-coat is proposed for corrosion control of the brackets, steps, struts and supports in the LVSA1. Fuel tank straps will be primed, painted and undercoated between the fender and the fuel tank.

Recommendations for LVSR: It is recommended that the brackets, steps, struts and supports on the LVSR be galvanized and phosphatized prior to E-coat. The galvanizing should be performed after fabrication of these components and should have a minimum thickness in the range of 0.8 to 1.7 mil. For the LVSR fuel tank straps, use of galvanized steel followed by prime and paint should be considered. For longer term corrosion protection, fuel tank straps designed using polymer matrix composites (fiberglass) should be considered.

2.8 TIRE HOIST.

LVSA1 Recommendations: This LVS component consists of a post, a pulley, a tire hoist bracket and a tire carrier. These parts are made of primed and painted carbon steel and will be E-coated for the LVSA1. Due to the severe wear and tear associated with this application, it is expected that the E-coat will likely fail and corrosion will be encountered.

Recommendations for LVSR: For the LVSR, it is recommended that the post, tire bracket and tire carrier parts be hot dip galvanized to 0.8 to 1.7 mil followed by zinc phosphate conversion coating and E-coat. The pulley should be manufactured using 17-4 PH stainless steel, hardened to a H1100, or an alloy with the equivalent corrosion and wear resistance.

3.0 ELECTRICAL COMPONENTS. The following LVS electrical system components were reported to be susceptible to corrosion induced failures and were identified as requiring corrosion control improvements for the LVSR system.

3.1 ELECTRICAL TERMINALS.

LVSA1 Recommendations: Electrical terminals on cab circuit breakers and cab switches, low air switches and stop light switches. These terminals are made of steel and will corrode. The LVSA1 will utilize Cortec VCI-238 for coating these terminals.

Recommendations for LVSR: An alternative coating that should be suitable for LVSR application is TECTYL 846, Class 1.

3.2 ELECTRICAL CONTROL BOXES AND ASSEMBLIES.

LVSA1 Recommendations: Corrosion due to moisture intrusion has been reported as a severe problem in various LVS actuator box, junction box, and hand control assembly units. No specific corrosion control measures were identified for these components in the LVSA1.

Recommendations for LVSR: All service access panels should be gasketed using polypropylene materials, because they withstand the requirement for repeated opening and closing while maintaining shape/integrity. For lids or openings that are not designed for repeated access, rubber type gaskets should be employed. All penetrations in these units should be waterproofed. All connectors and plugs that penetrate the sides and bottom of these boxes should be the waterproof type. All wire harnesses entering the boxes should be cord gripped. The wiring harnesses external to the boxes should be designed to include a "drip loop". Desiccant packs should be placed inside of these units to absorb and moisture that penetrates the units.

4.0 PNEUMATIC AND HYDRAULIC COMPONENTS. The following LVS pneumatic and hydraulic system components were reported to be susceptible to corrosion and were identified for corrosion control improvements in the LVSA1 system.

4.1 <u>AIR RESERVOIR AND BRACKETS</u>.

LVSA1 Recommendations: These components are manufactured from carbon steel and were treated with SAE J10 black primer. For the LVSA1, these black primed components will also be painted in accordance with MIL-T704K.

Recommendations for LVSR: It is recommended that the reservoir be galvanized or primed with zinc silicate followed by phosphatizing and E-coat for the LVSR.

4.2 <u>AIR FITTINGS</u>.

LVSA1 Recommendations: For the LVSA1, these carbon steel fittings are to be coated to a thickness of 1 to 2 mils using Cortec VCI-386, a liquid that provides a composite polymer barrier. It is noted that brass is being required by the USMC for the quick disconnect air fittings on LVSA1.

Recommendations for LVSR: It recommended that brass fittings conforming to ASTM-B-21-83b be considered for all LVSR air fittings attached to flexible lines. For those fittings attached to steel lines, it is recommended that the use of metallic Sn/30Zn, Zn/10Ni and IVD aluminum coatings and a hybrid chromium free Dorrlflake coating be considered.

4.3 BRAKE PNEUMATIC VALVE SPRING.

LVSA1 Recommendations: These carbon steel components are apparently suffering from both general and crevice corrosion in the LVS. The LVSA1 proposes to E-coat these components for improved corrosion resistance.

Recommendations for LVSR: It is recommended that 316 stainless steel be considered for this application in the LVSR because it has good general and crevice corrosion resistance.

4.4 HYDRAULIC RESERVOIR AND FILTER HOUSING CAP.

LVSA1 Recommendations: The reservoir is manufactured from carbon steel and is primed and painted. Corrosion is encountered on the surfaces between the bottom of the reservoir and the fender. This component will be undercoated at the corrosion susceptible locations for the LVSA1. The LVSA1 will use a coating of Cortec VCI-386 and a topcoat on the filler cap.

Recommendations for LVSR: While the application of undercoat is appropriate, it is recommended that zinc silicate be used for the primer on the reservoir for the LVSR. VCI-386, to be used on the filler cap, is a barrier coating that will likely be damaged during normal operations. Therefore, it is recommended that a zinc silicate primer be used on this component, followed by a topcoat. A redesign of the cap should be considered to eliminate the recess/cavity in the current design.

4.5 HYDRAULIC FITTINGS AND FASTENERS.

LVSA1 Recommendations: For the LVSA1, the carbon steel fittings are to be coated to a thickness of 1 to 2 mils using Cortec VCI-386.

Recommendations for LVSR: It is recommended that 316 stainless steel fittings conforming to ASTM-A-167-Type 316 be considered for all LVSR hydraulic fittings attached to flexible lines. For those fittings attached to steel lines, it is recommended that the use of metallic Sn/30Zn, Zn/10Ni and IVD aluminum coatings and a hybrid chromium free Dorrlflake coating be considered.

4.6 RADIATORS AND TRANSMISSION AND HYDRAULIC COOLERS.

LVSA1 Recommendations: With regard to the radiators, the LVSA1 will apply a coating of Heresite P-413 to the steel core. With regard to the transmission and hydraulic coolers, the LVSA1 will use a copper tube and fin core with a Heresite P-413 coating. This copper core and fin radiators and associated technology was developed in conjunction with the Copper Development Association and has undergone significant successful tests.

Recommendations for LVSR: It is recommended that performance of the copper core radiator technology proposed for the LVSA1 be monitored and, based on results, be considered for both the LVSR transmission and hydraulic coolers, as well as for the LVSR radiator application. In addition, testing of a nylon radiator under the USMC corrosion control program indicates that this technology should also be considered for the LVSR radiator application.

5.0 BATTERY AND POWER TRAIN COMPONENTS.

The following LVS battery and power train system components are reported to be susceptible to corrosion, and were identified for corrosion control improvements in the LVSA1 system.

5.1 BATTERY BOX.

LVSA1 Recommendations: The LVS battery box is made of carbon steel with a zinc oxide coating. The LVSA1 will use a non-corroding polymer matrix composite material for this component. This appears to be an appropriate measure provided the resin and the design of the box are such to preclude accumulation of and damage from battery acid.

Recommendations for LVSR: It is recommended that the battery box be fabricated using polypropylene matrix composite, since this thermoplastic resin material is reportedly highly resistant to battery acids. Another option to be considered for the LVSR is application of a thermal spray coating of ethylene methacrylic acid copolymer, which was sprayed onto interior and exterior bottom surfaces of a steel battery box on a 939 Series 5-ton truck, and is currently undergoing field testing in the USMC corrosion control program.

5.2 AIR CLEANER ASSEMBLY (SUPERCLONE).

LVSA1 Recommendations: This component is made of steel and painted. The location and design of the air cleaner assembly on the LVS results in significant physical abuse producing damage to the coating and accumulation of water inside the assembly. This situation results in both general and crevice corrosion. For the LVSA1, this component is being structurally redesigned to prevent water from entering the assembly. An undefined epoxy primer and a green topcoat will also be applied.

Recommendations for LVSR: While the performance of this redesigned air cleaner assembly should be monitored, the application of zinc silicate versus the unknown epoxy primer should be considered. Another option for this includes the use of galvanized steel followed by phosphatizing and E-coat.

5.3 PROPULSION SHAFTS.

LVSA1 Recommendations: The propeller and drive shafts are made of carbon steel. In the LVS, these components are coated with an unknown primer and suffer from severe surface corrosion. In the LVSA1, the shafts will be painted to MIL-T-704K.

Recommendations for LVSR: The options for this application range from coating with a zinc silicate primers, thermal spray coating/cladding with Inconel 625 to design of a fiber reinforced composite shaft. The cost of implementing these options increases significantly if one moves from zinc silicate to a composite shaft. However, there is a good technology base for each of these options and these should be explored for the LVSR.

5.4 EXHAUST COMPONENTS.

LVSA1 Recommendations: These components on the LVS include the manifold, exhaust elbow, exhaust pipe connector, turbo intake pipe, turbocharger assembly and exhaust outlet. The LVSA1 will continue to use these materials.

Recommendations for LVSR: It is recommended that the following options be considered for the LVSR. For the manifold and turbocharger assembly, apply a high temperature coating, such as Dampney Thermolox (in USMC test program) or Sermagard. For the exhaust elbow, pipe connector and outlet, use aluminized 409 stainless steel.

6.0 SUMMARY OF RECOMMENDATIONS FOR LVSA1 AND LVSR.

Table ES-1 summarizes the corrosion control technologies to be applied to the LVSA1 and the recommendations for the LVSR.

Table ES-1 LVSA1 Suggestions and LVSR Recommendations

Subsystem	Component	LVSA1 Technology(s)	LVSR Recommendation(s)
Body and Chassis	Cab	E-coat and undercoat/rustproofing, drain holes	Zinc silicate primer/ zinc phosphate conversion coating/E-coat
	Fenders	Galvanneal, E-coat and undercoat/rustproof	Same
	Cargo body and dropsides	E-coat and undercoat/rustproof	Hot dip galvanneal/zinc phosphate/E-coat
	Radiator grille/grate assembly	E-coat (grille); galvanneal steel (grate)	Polymer matrix composite
	Tool boxes	E-coat and undercoat	Aluminum thermal spray
	Brackets, steps, struts, supports and fuel tank straps	E-coat (brackets, steps, struts, supports); prime, paint and undercoat (fuel tank straps)	Galvanize, zinc phosphate, E-coat (brackets, steps, struts, supports); galvanize, prime and paint (fuel tank straps)
	Tire hoist	E-coat	Hot dip galvanize, zinc phosphate, E-coat
Electrical	Electrical terminals	Cortec VCI-238	TECTYL 846, Class I
	Electronic control boxes and assemblies	None	Waterproof, polypropylene and rubber gaskets
Pneumatic and Hydraulic	Air reservoir and brackets	Black primer	Galvanize or zinc silicate primer, zinc phosphate, E-coat
	Air fittings	Cortec VCI-386; brass (quick disconnect)	Brass; Sn/30Zn, Zn/10Ni, IVD aluminum, Dorrlflake (fittings attached to steel lines)
	Brake pneumatic valve spring	E-coat	316 stainless steel
	Hydraulic reservoir and filter housing cap	Undercoat (reservoir); Cortec VCI-386 and topcoat (cap)	Zinc silicate primer and e-coat (reservoir); zinc silicate and topcoat (cap)
	Radiators and transmission and hydraulic coolers	Heresite P-413 (radiators); copper tube and fin core with Heresite-P413 (coolers)	Evaluate results of LVSA1; nylon (radiators)
Battery and Power Train	Battery box	Polymer matrix composite	Polypropylene matrix composite, ethylene methacrylic acid copolymer thermal spray
	Air cleaner assembly (superclone)	Structurally redesigned, epoxy primer, green topcoat	Evaluate results of LVSA1; substitute zinc silicate as primer
	Propulsion shafts	Painted to MIL-T-704K	Zinc silicate, thermal spray with Inconel 625, fiber reinforced composite
	Exhaust components	None	Thermolox or Sermagard (manifold, turbocharger assembly); aluminized 409 stainless steel (exhaust elbow, pipe connector,

II. INVESTIGATIVE ANALYSIS

1.0 BACKGROUND. In 1985, the Marine Corps fielded the Logistics Vehicle System (LVS), a series of 22.5 ton trucks designated the MK48 series. The MK48 series truck is comprised of two separate chassis modules that are coupled together through an articulation joint to form an integral all wheel drive vehicle. The front power module (MK48) includes a 445 horsepower diesel engine, a four-speed automatic transmission, and a two-speed transfer case. The rear modules come in the following body configurations each performing a specific mission as described below.

1.1 MK48/MK14 LOGISTICS PLATFORM TRUCK. The MK14 rear body module has a 20-foot steel flat deck with ISO pockets to transport one 8'x8'x20', two 8'x8'x10', or six SIXCON containers.

1.2 MK48/15 WRECKER/RECOVERY VEHICLE. The MK48/15 has an 11-foot steel cargo body with fore/aft storage compartments. It mounts a 9,000 knuckle boom crane and a 60,000 lb winch used to recover disabled vehicles. It also provides hydraulic power to operate power tools. The wrecker/recovery vehicle can lift and tow all of the commercial and tactical vehicles in the Marine Corps inventory.

1.3 MK48/16 TRUCK TRACTOR. The MK48/16 has a fully oscillating fifth wheel for 3.5 inch kingpins with trailer air and electrical connections and a 60,000 lb winch used to winch disabled vehicles onto the semi trailer. The MK48/16 is designed to tow the M870 and the M1000 semi trailers.

1.4 MK48/17 CARGO TRUCK WITH MATERIAL HANDLING CRANE. The MK48/17 has a 16 foot steel cargo body with fold down side that contain troop seats. It also has a 9,000 lb material handling crane.

1.5 MK48/18 RIBBON BRIDGE CONTAINER HAULER. The MK48/18 has a lifting gear assembly mounted at the rear and a winch assembly mounted on the front of a split bed.

The MK18 is capable of self-loading and unloading the ribbon bridge set and ISO cargo containers through the use of the lifting gear assembly.

2.0 PURPOSE. The purpose of this analysis was to determine and document the extent of corrosion problems on the LVS. Corrosion identified was categorized into one of four stages in order to communicate the condition of the metal. The four stages can be found in TM 4790-35 and are as follows:

- Stage 1 Rust: The painted surface is bubbly or the paint bubbles have broken to reveal rusty red, black, or white corrosion deposits on the metal surface. This may be accompanied by minor etching or pitting of the metal. In Stage 1 rust, no scale is present but the metal may have loose, powdery, or granular deposits on the surface. Base metal is sound.

- Stage 2 Rust: Powdered, granular, or scaled condition exists on the surface metal. Rusty red, black, or white corrosion deposits are present. Metal surface may be etched or pitted. Metal beneath the corroded area is still sound.

- Stage 3 Rust: Surface conditions and corrosion deposits present are similar to Stage 2 except that metal in corroded area is unsound, and small pin holes may be present.

- Stage 4 Rust: Corrosion has advanced to the point where the metal has been penetrated throughout. No metal remains at the point of severest corrosion. There are holes in the surface area or metal is completely missing along the edges.

Once the corrosion has been identified and categorized, specific recommendations to alleviate the corrosion problem(s) were made.

3.0 OBJECTIVE. The objective of this investigation was to identify corrosion prone areas on the LVS, determine the cause of the corrosion, and to make specific recommendations to alleviate the cause of the corrosion. These recommendations are based on technologies that have potential for improved corrosion resistance and reduced life cycle cost for use in the LVSR. In addition, this investigation was to provide performance based specification criteria for recommended LVSR corrosion control technologies. The recommended technologies would be candidates for inclusion in the LVS ATD and/or other LVSR-related government corrosion control test efforts.

4.0 APPROACH. Our approach to this analysis was to identify LVS corrosion prone areas through literature searches and vehicle inspections. Specific corrosion prevention recommendations measures were made based on the latest corrosion prevention technologies and government tests in the marine environment. .

4.1 <u>LVS CORROSION PRONE COMPONENT CHARACTERIZATION</u>. Characterization of corrosion prone components was accomplished during field visits, and literature reviews.

4.1.1 FIELD VISITS. A vehicle inspection trip to Camp Lejeune, North Carolina, and a trip to the Marine Corps Logistics Base, Albany, Georgia, uncovered a number of corrosion-prone components. The inspection trips documented the type, extent and likely cause(s) of corrosion on each component. During these field visits, it was discovered that there were essentially four levels of corrosion protection in the Marine Corps LVS fleet.

4.1.1.1 Standard LVS. These are the vehicles that were fielded in 1985. Other than spot painting, these vehicles have the factory original corrosion protection.

4.1.1.2 IROAN LVS. These vehicles had been through the MCLB, Albany Inspect and Replace Only As Necessary vehicle refurbishment line. The oldest was 2.2 years since IROAN. During the IROAN process, corrosion was reduced by sandblasting, undercoating, and topcoating with water-borne camouflage paint.

4.1.1.3 Corrosion Control LVS. These vehicles had been sandblasted and undercoated at the MCLB, Albany, most within the last 2 years. Other corrosion was reduced by sandblasting, undercoating, and topcoating with water-borne camouflage paint.

4.1.1.4 LVSA1. The LVSA1 program was initiated to replace inventory deficiencies and to augment selected fleet Marine force transportation capabilities. The LVSA1 is a newer version of the LVS that was fielded in 1985. Based on Marine Corps corrosion concerns, Oshkosh Trucking Company (OTC) was tasked to identify corrosion control options for the identified subsystems and components. In order to maintain commonality, the LVSA1 contains few new technologies. However, based upon Marine Corps documentation which details LVS corrosion problems, OTC made a number of recommendations to reduce the corrosion problems for the LVSA1. Although the corrosion control technologies incorporated into the LVSA1 are expected to improve performance compared to the LVS, the USMC has initiated evaluations of a full range of technologies to support the LVS Replacement (LVSR). Reference (1) presents the OTC corrosion control recommendations which are currently being implemented in the LVSA1.

4.2 LITERATURE REVIEW.

4.2.1 References (1) through (7) were reviewed to establish a listing of corrosion prone LVS subsystems and components. References (2), (3), (6) and (7) provided valuable insight into the corrosion problem for a number of vehicles including the LVS. Specific corrosion-prone areas with pictures were identified. Reference (4) is a Reliability Analysis Center report which provided historical maintenance data on the high dollar or hard to get LVS repair parts. While this report did not specifically identify parts that failed due to corrosion, we were able to match parts identified in previous analyses with its maintenance history. The utility of reference (4) prompted commission of reference (285) which is an analysis of LVS repair parts history going back 9 years.

4.2.2 Reference (1) is the Oshkosh Truck Corporation recommendation for corrosion prevention for the LVSA1. This proposal included specific components and corrosion control measures proposed for the LVSA1.

4.2.3 The type of material, the cost and the NSN number for each item was determined by researching the Haystack database. Haystack is a computer-based search and retrieval system providing complete information on any of the thirteen million parts purchased by the U.S. Government.

4.2.4 Based on review of the corrosion prone component characteristics, a literature review was conducted to identify available data on the marine corrosion performance of the various options proposed for the LVSA1, and to identify other corrosion control options and associated corrosion performance data for each component. In addition, material and component suppliers were contacted to identify costs associated with implementing the various corrosion control options.

4.2.5 The literature review included Internet searches of web pages that included technical societies, technical organizations, and Thomas Register of American Manufacturers. In-house resources, such as handbooks, CDNSWC reports, text books and recent technical society publications were also reviewed. When sources of materials and coatings were contacted, the literature they supplied or referenced was also reviewed.

4.3 CORROSION ASSESSMENT. The LVS was broken down into four major subsystems: 1.) Body and Chassis, 2.) Electrical, 3.) Pneumatic and Hydraulic, and 4.) Battery and Power Train . As shown in Table 5.1, each subsystem was further broken down into components. The components were grouped together based on their geometry, base material, and/or potential corrosion control measures. For each component the following characteristics were evaluated:

- The material and corrosion control measures specified for the original LVS;

- The type, extent and likely cause(s) of corrosion encountered by the component;

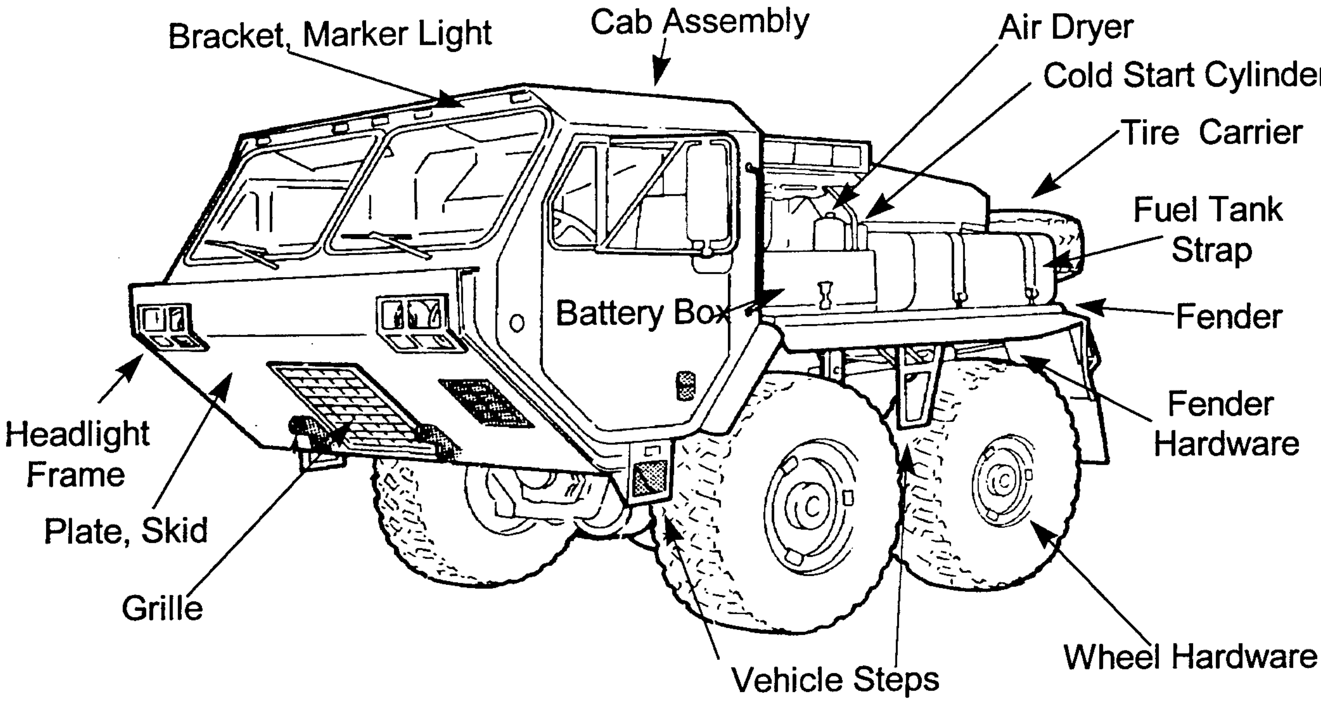
- The proposed LVSA1 corrosion control measure, if any.

The corrosion control option proposed for each component in the LVSA1 was assessed based on its potential effectiveness and cost. Effectiveness of the LVSA1 option was judged by considering the type of corrosion encountered by the component and by comparison with other potential corrosion control options identified from the literature review. Recommended corrosion control options were developed for each component.

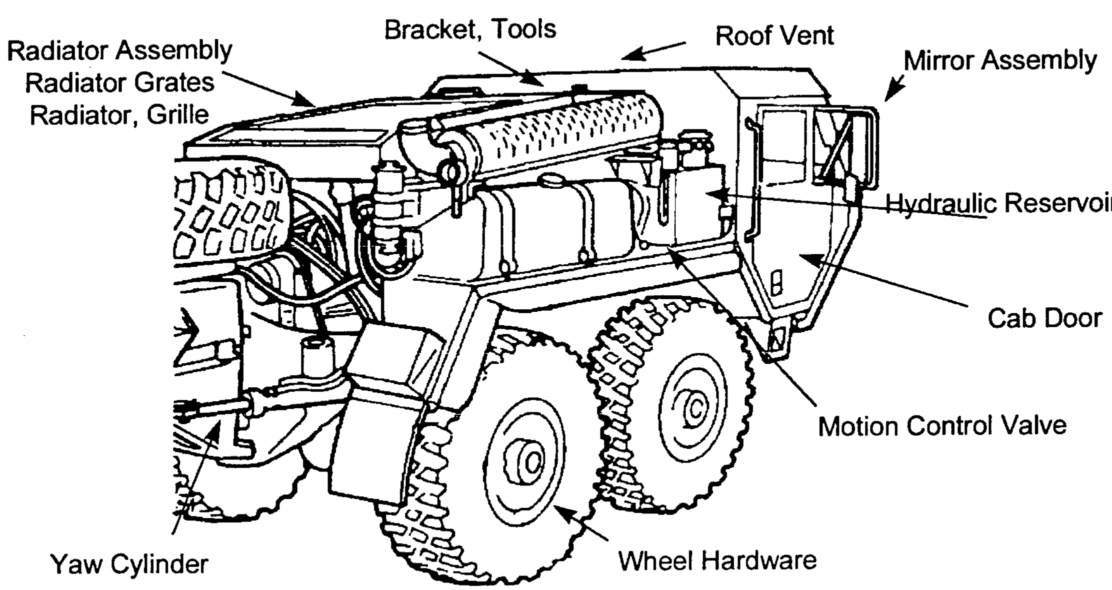
4.4 PERFORMANCE-BASED SPECIFICATIONS. Performance-based specification criteria were identified for each recommended LVSR corrosion control technology. The criteria include the military or commercial specification that governs composition/material processing, as well as the minimum corrosion performance that the technology can be expected to provide. The latter information was determined from the literature review performed in this investigation. Thus, the performance based specification criteria can be used as a basis for purchase of the recommended technology or for evaluation of the potential of other corrosion control technologies proposed for the LVSR.

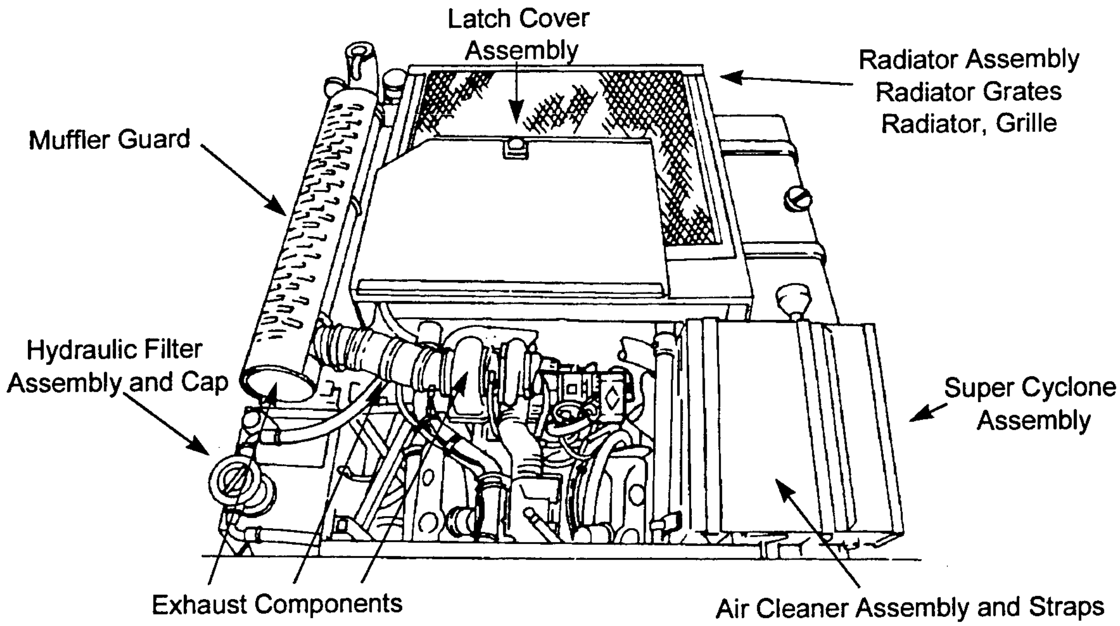
5.0 RESULTS.

The following drawings are provided to orient the reader to the corrosion prone areas on the LVS:

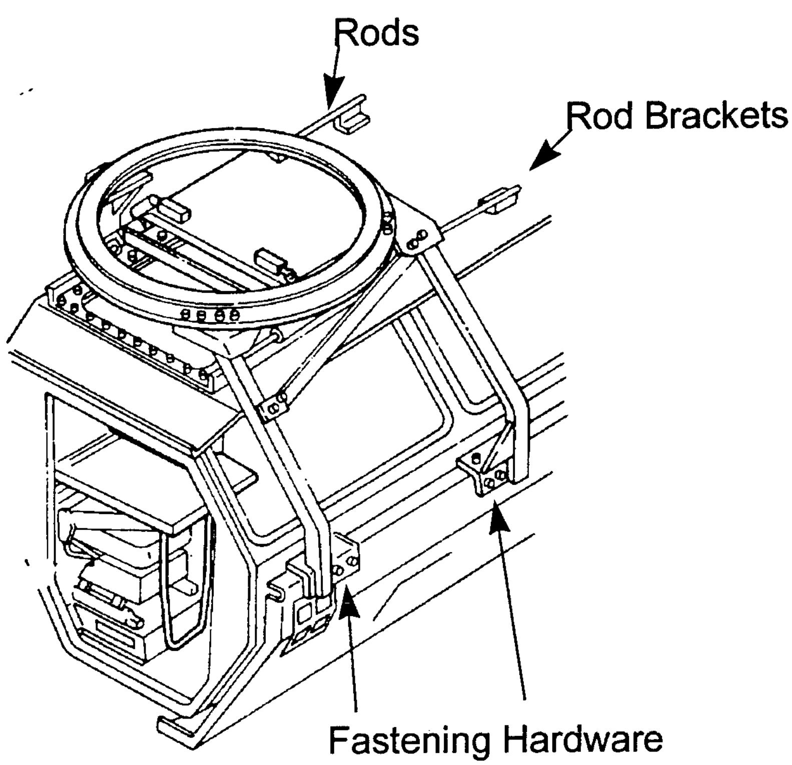


MK 48 FRONT POWER UNIT

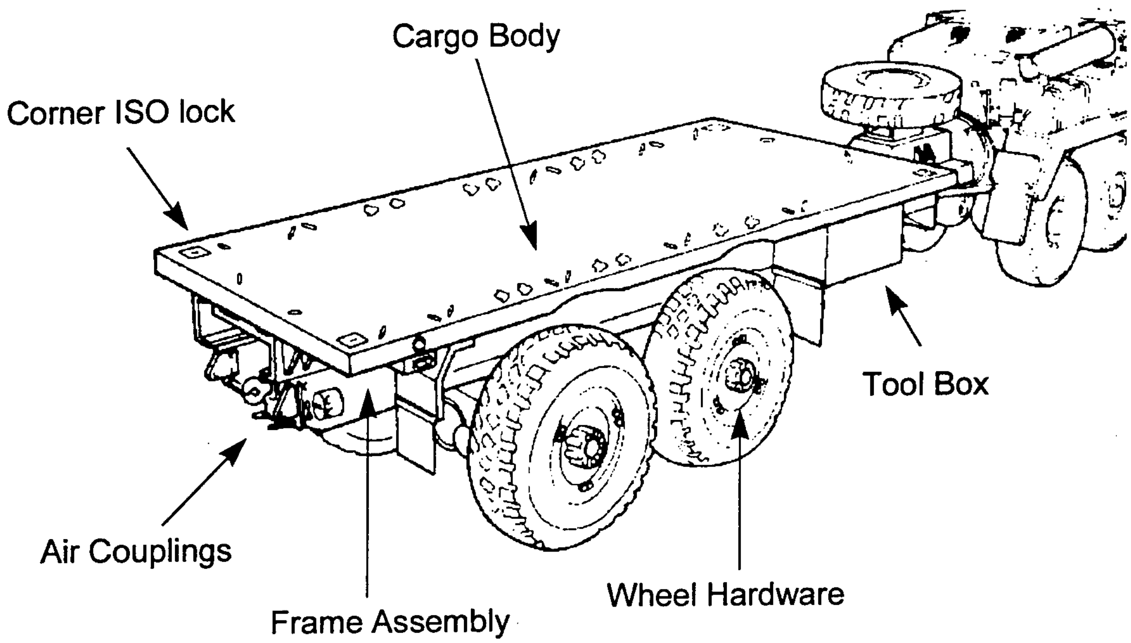




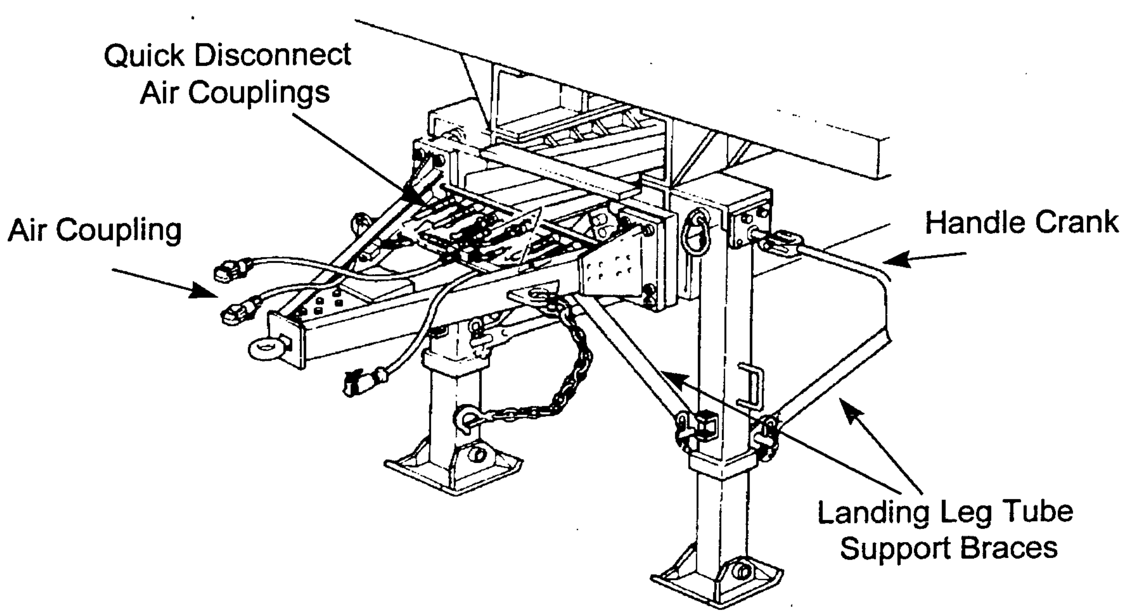
MK 48 ENGINE COMPARTMENT



MK 48 MACHINE GUN MOUNT



MK 14 TRAILER, POWERED, CONTAINER HAULER



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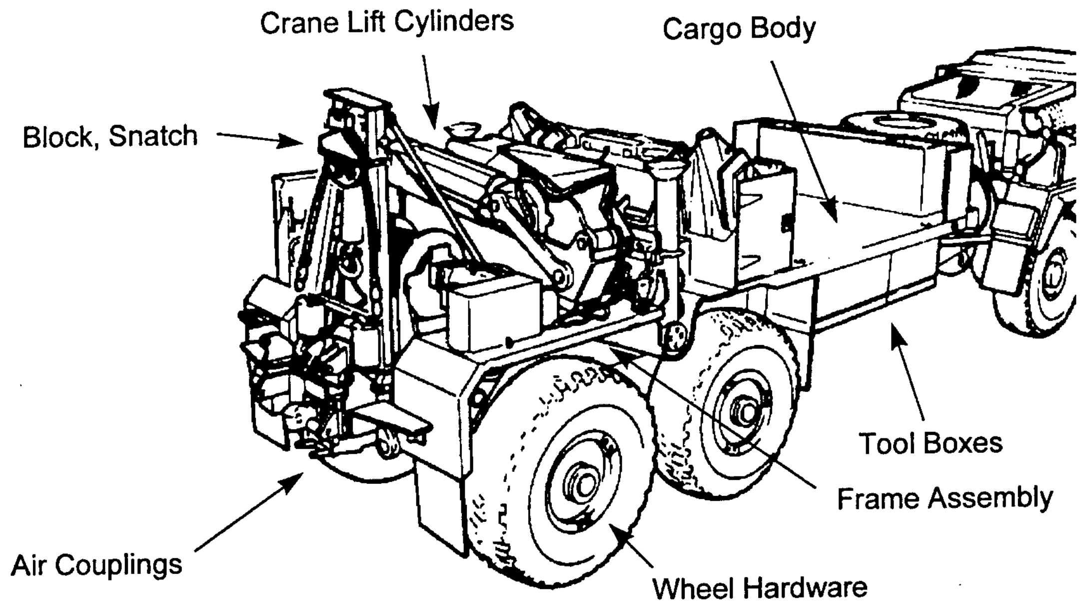
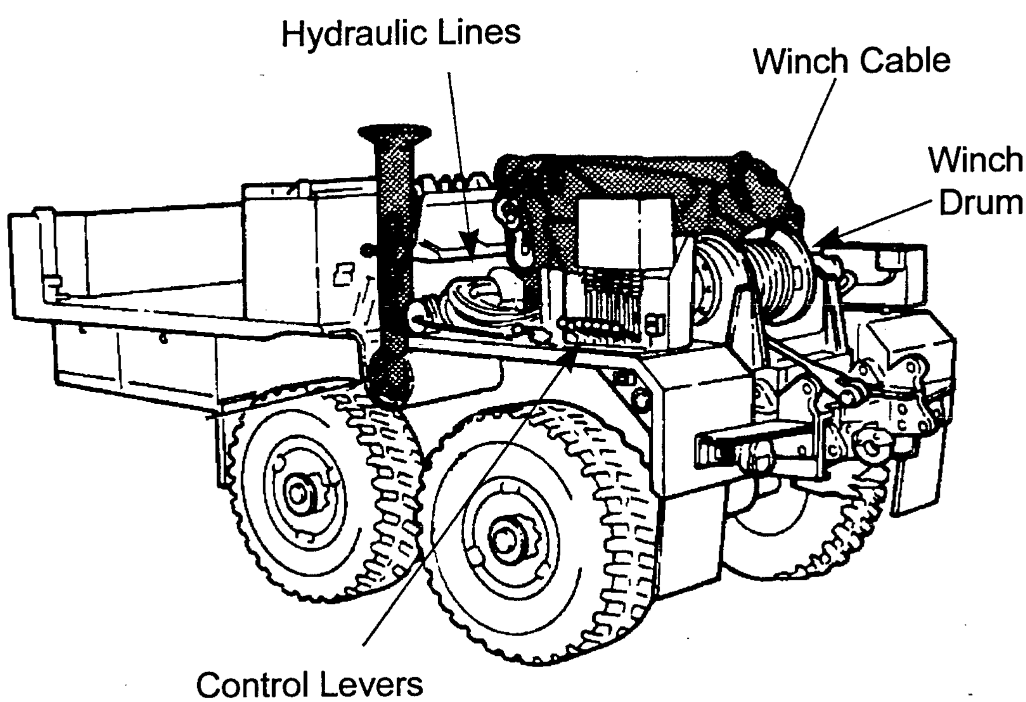
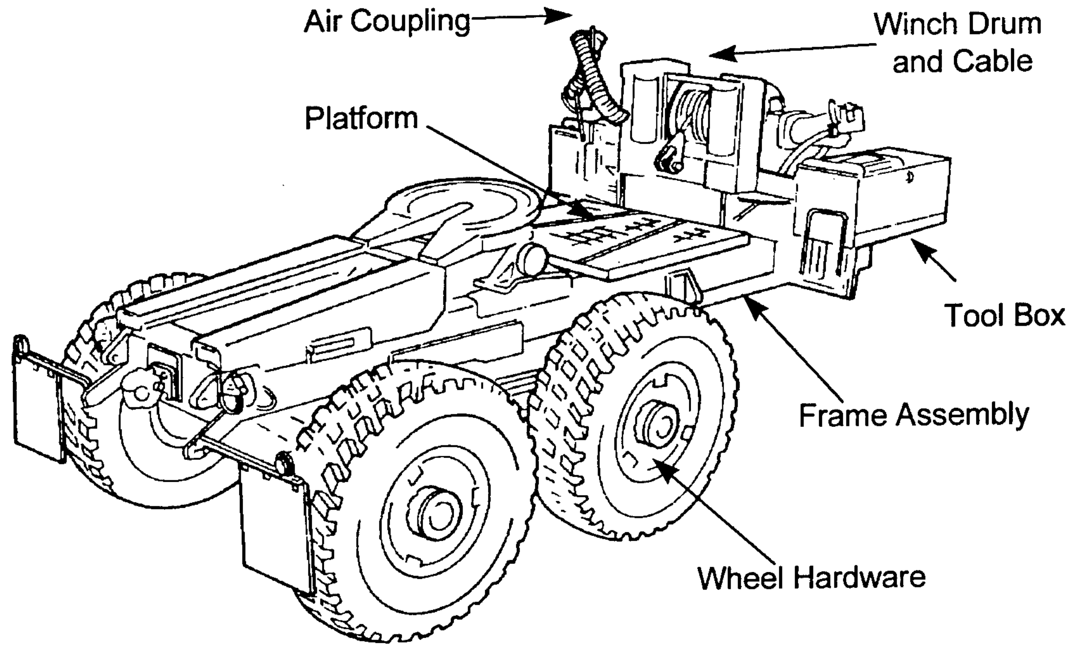
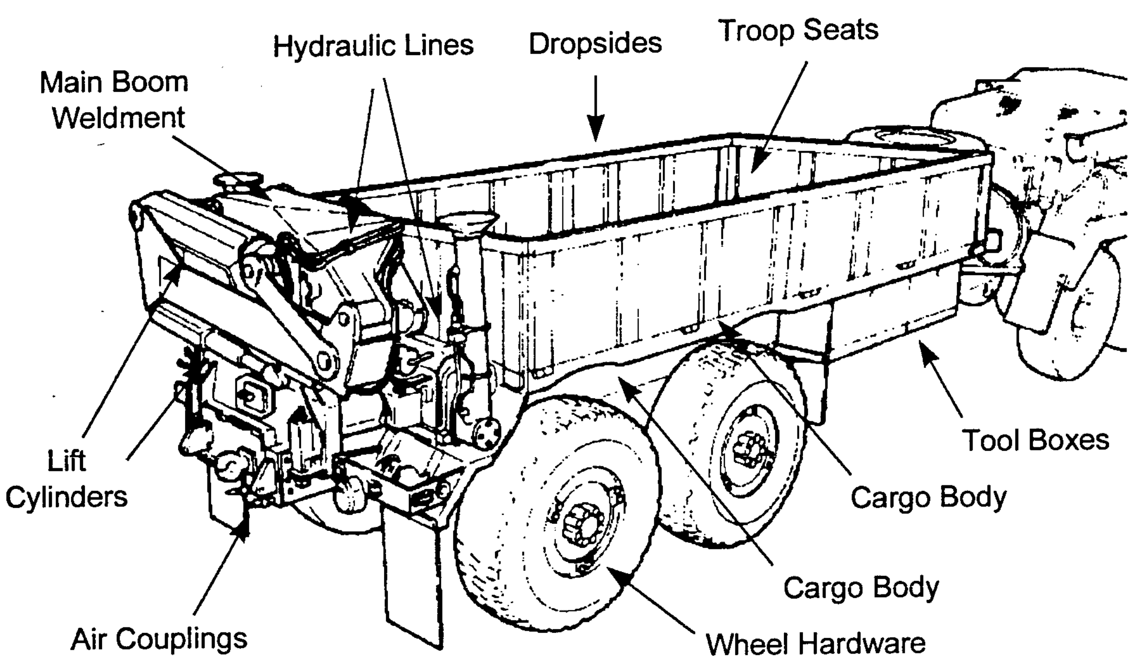


MK 15 TRAILER, POWERED, WRECKER RECOVERY

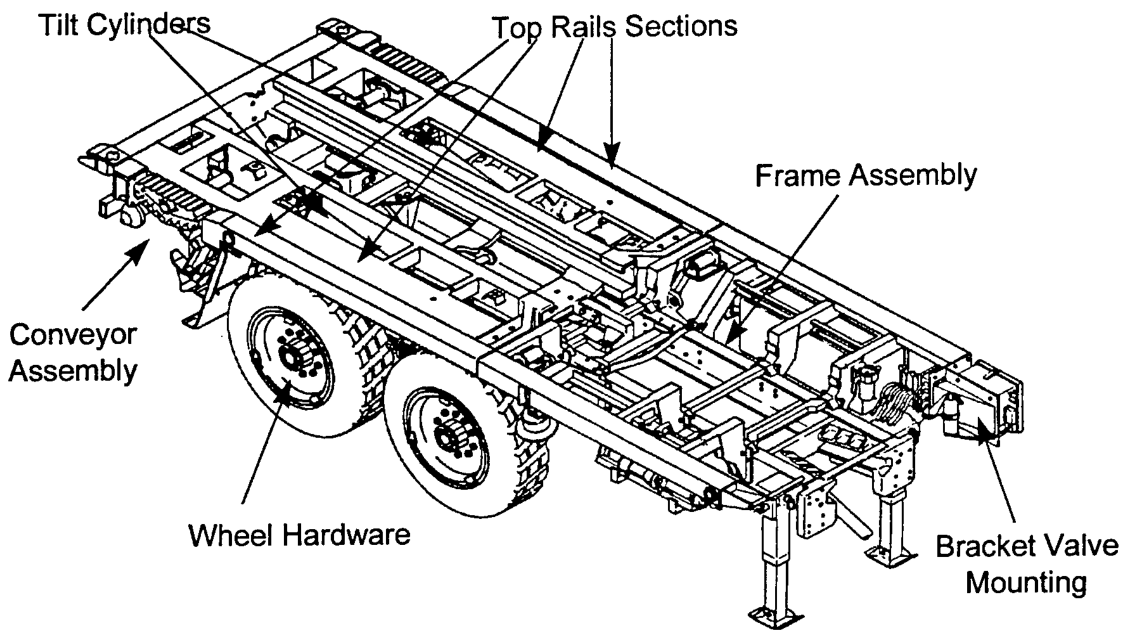




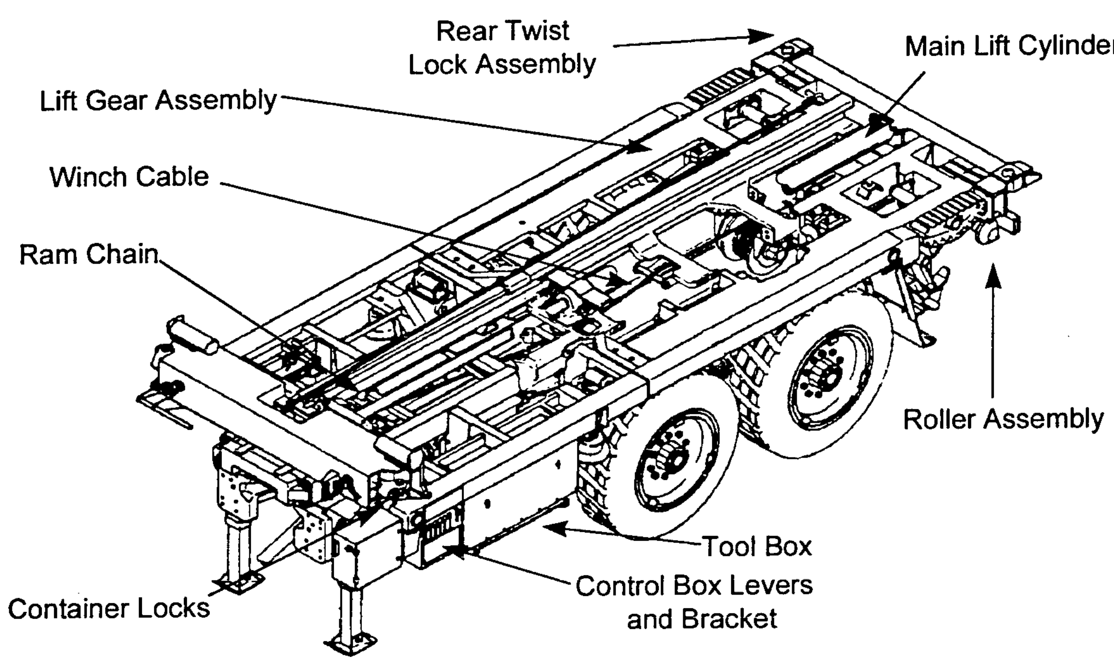
MK 16 TRAILER, POWERED, 5TH WHEEL SEMITRAILER ADAPTER



MK 17 TRAILER, POWERED DROPSIDE CARGO, WITH CRANE



MK 18 TRAILER, POWERED, RIBBON BRIDGE/CONTAINER HAULER



5.1 <u>LVS CORROSION-PRONE COMPONENT CHARACTERIZATION</u>. Appendix A lists the corrosion prone LVS components identified during this investigation. The table presents the NSN, part number/cage code, and cost for each component. In addition, the specific LVS configuration(s) on which the corrosion prone component is located is presented. The information on Table A-1 is grouped by the major LVS subsystem identified on Table 5.1. It is noted that the cost of the components value from a few cents to several thousand dollars. However, this cost is for purchase of the component and does not include labor costs due to maintenance action on the component. Therefore, components that seem to have an insignificant initial cost may prove to be expensive, when considering impact on readiness or maintenance costs. The extent and type of corrosion determined for each of the LVS subsystems listed in Table 5.1 is presented in Section 5.3 as part of the assessment.

Table 5.1- LVS Subsystems and Components Evaluated for Improved Corrosion Control Technologies

Subsystem	Component
1. Body and Chassis	a. Cab
	b. Fenders
	c. Cargo Bodies and Dropsides
	d. Radiator Grille/Grate
	e. Tool boxes
	f. Brackets, Steps, Struts, Supports, and Fuel Tank Straps
	g. Tire Hoist
	h. Cab Doors
2. Electrical Components	a. Electrical Terminals
	b. Electronic control Boxes and Assemblies
3. Pneumatic and Hydraulic Components	a. Air Reservoir and Brackets
	b. Air Fittings
	c. Brake Pneumatic Valve Spring
	d. Hydraulic Reservoir and filter housing cap
	e. Hydraulic Fittings
	f. Radiators and Transmission and Hydraulic Cooler
	g. Miscellaneous Fasteners
4. Battery and Power Train Components	a. Battery Box
	b. Air Cleaner Assembly (Superclone)
	c. Propulsion Shafts
	d. Exhaust Components

5.2 LITERATURE REVIEW. The literature review focused on identifying corrosion control technologies that have potential for the LVSR. The technologies reviewed included those being implemented in the LVSA1, as well as others with potential for providing improved performance. Table 5.2 presents the corrosion control technologies identified during the investigation and includes a description of the technology, corrosion performance data for the technology, and the cost for the technology.

5.3 CORROSION CONTROL ASSESSMENTS.

5.3.1 The results of the LVS corrosion control assessment are presented in this section. For each component identified on Table 5.1, the original material and corrosion control measure specified for the LVS are identified. This is followed by a description of the type and extent of corrosion based on the literature searches and field surveys. The LVSA1 corrosion control option for the component is then identified. This is followed by an assessment of the LVSA1 and other corrosion control options identified in this investigation. The assessment considers the potential corrosion performance (based on results of the literature review) and cost (if available) to implement each option. In some cases, cost information that would facilitate comparisons between corrosion technologies was not available. Based on the assessment, a recommended corrosion control option for the LVSR is presented for each component.

Table 5.2 - Results of Literature Search on Corrosion Performance and Cost of Potential LVS Corrosion Control Technology

Technology	Description	Corrosion Performance Data	Cost
Brass C36000 (Half Hard free cutting)	A leaded Brass with a 44-52 ksi yield strength.	Marine atmosphere: 0.056 mils/yr of loss in 20 yr study in La Jolla, CA ; Ref (5)	\$1.05 per 3/8" tube nut fitting \$0.78 per 3/8" fitting in carbon steel$_{(1)}$
Fiberglass with polypropylene resin	Chopped nylon fibers with polypropylene resin formed to a particular shape.	Under evaluation by CDNSWC	N/A
17-4PH Stainless Steel ASTM-A705-Type 630	A precepitation hardened martensitic stainless steel that contains 17Cr-4Ni-4Cu alloy.	Rusts only superfacially in marine atmospheres. Susceptable to slow crevice corrosion, pitting, and edge corrosion in seawater.	\$2.62/lb $_{(2)}$ for 1" dia bar
316 Stainless Steel ASTM-A 167-Type 316	A austinictic Chrome Nickel stainless steel that contains 16Cr, 10Ni alloy.	Marine atmosphere: 0.001 mils/yr slight rust on 15% of surface at Kure Beach, NC; Ref (5)	\$2.66 per 3/8" tube nut fitting verses \$0.78 per 3/8" fitting in carbon steel $_{(1)}$
409 Stainless Steel ASTM-A 176-Type 409	A ferritic stainless steel that contains 10.5 Cr, 1Mn, 1Si and 0.75Ti alloy.	Under evaluation by CDNSWC	N/A
Mild Steel MIL-B-13207D	A 0.30 % carbon steel with a minium yield strength of 35 ksi.	Immediate Corrosiòn	\$.75/lb $_{(2)}$ for 1" dia bar
Aluminized 409 Stainless Steel ASTM A463	Forming of Aluminium alloy onto 409 Stainless Steel substrate by hot dipping, hot spraying, or diffusion.	Under evaluation by CDNSWC	N/A
Aluminum Thermal Spray coating MIL-C-46168	A thermal spray process in which the Aluminum is melted and propelled against a steel substrate by hot, ionized gas.	Marine atmosphere: 0.001 mil/yr based on 0.01 mils after 16 Years at Cristobel, Panama; Ref (5)	10.42 cents/in^2 @ 5.0-7.0 mils
Galvanneal Steal	A zinc10%-iron alloy coating that is produced by keeping the hot dip galvanizing molten until the Zinc alloys completely with the base steel.	Marine Atmosphere: <0.2 mil/yr Ref(5)	<0.596 cents/in^2 @0.8-1.7 mils
Hot Dip Galvanize coating ASTM A 123-89a	A process by which a steel substrate is placed into a molten bath of zinc.	Marine atmosphere: 0.2 mil/yr based on 12 years before rust on surface @2.4 mils at Sandy Hook, NJ ; Ref (5)	0.596 cents/in^2 @0.8-1.7 mils
Sn-Zn coating PS-8956 w/Cr	Electrodeposition of Tin-Zinc (70%-30%) alloy onto a metal surface from an alkaline type bath specification calls for a chromate conversion coating.	ASTM B117: 400 hr @0.4 mils without chromate; 2000hr @ 0.4 mils with chromate	0.015 cents/in^2 @ 0.4 mils
Zn-Ni coating AMS-2417E w/o Cr WSA-M1P87-A1 w/Cr	Electrodeposition of Zinc-Nickel (90%-10%) alloy onto a metal surface from an alkaline type bath with or without chromate conversion coating.	ASTM B117: 400 hr @0.4 mils without chromate; 3500hr @0.3 mils with chromate	0.016 cents/in^2 @0.4 mils
Ion Vapor Deposited (IVD) Aluminum coating MIL-C-43488	Vacuum process where aluminum vapor is attracted to the negatively charged work piece.	ASTM B117: 336 hrs @ 0.5 mils, from MIL spec	24 cents/in^2 @ 0.5 mils
Dorrlflake coating GM7111M	Multilayered coating system of an inorganic zinc flake base coat and an aluminum tinted epoxy top coat.	ASTM B117: 1000hr @ 0.5-1.0 mils, from GM spec	N/A

Table 5.2 - Results of Literature Search on Corrosion Performance and Cost of Potential LVS Corrosion Control Technology

Technology	Description	Corrosion Performance Data	Cost
SermaGuard coating MIL-C-81751B	A ceramic binder containing dispersed aluminum particles that provides both barrier and sacrificial corrosion protection at temperatures up to 1200 F	ASTM B117: 1500 hr B117 @2.0 mils Manufacturer Supplied Data	15.24 cents/in^2 @2.0 mils
Cortec VCI-238 coating	An electronic aerosol or liquid spray that forms a dry, film that inhibits galvanic or dissimilar metal corrosion encountered in electronic system applications.	ASTM D1648: +80 days on copper Manufacturer Supplied Data	0.042 cents/in^2 53.27/gallon
Cortec VCI-386 coating	A liquid that provides a composite polymer barrier coating.	ASTM B117: 120 hr @2.0 mils Manufacturer Supplied Data	0.034cents/in^2 @ 2.0 mils
Heresite P-413 coating MIL-C-18467	A phenolic thermosetting resinous coating designed for use on fin tube coils	ASTM B117: 3000 hr @2.0-3.0 mils Manufacturer Supplied Data	0.11cents/in^2 @2.0-3.0 mils
Tectyl-846 coating MIL-C-16173E(grade 4, class 1)	A solvent cutback, water displacing corrosion prevention compound.	ASTM B117: 1000 hr @1.0 mil Manufacturer Supplied Data	0.0059 cents/in^2 6.53/gallon @ 1.0 mil
Rustproof\Undercoating MIL-C-62218A SAE J1959 JUN89	A tacky barrier type coating that repels water and protects against impact	ASTM B117: 100 hr from SAE spec	19.25 cents/oz
Zinc Silicate Primer AASHTO-M300	A primer available as water based, solvent based or epoxy type that distributes a silicon base with interdepersed Zinc flakes onto a metal surface.	ASTM B117: 6500 hr @3.0 mils Manufacturer Supplied Data	0.39 cents/in^2 @3.0 mils
ElectroCoat (E-coat) MIL-P-53084	A dipping process that electrodeposits a dense, chromate free and relatively thin (0.5-1.5 mils) epoxy (for the LVSA1) barrier coating onto simple or complex shaped components.	ASTM B117: 500 hr B117 @1.5 mils Manufacturer Supplied Data	0.013 cents/in^2 @1.5 mils
Ameron PSX 738 coating MIL-P-14105D	A siloxane paint know for it's high heat resistance.	ASTM B117: 5500 hrs @7.0 mils Manufacturer supplied data	0.49 cents/in^2 @ 7.0 mils
Zinc Phosphate coating MIL-HDBK-205A / TT-C-490D Type V	Forming of a Zinc Phosphate coating on a metal by immersion or spray of an aqueous phosphate solution.	N/A	N/A

Note (1) Parker Fittings
(2) Cost for 1" dia bar stock

5.3.2 BODY AND CHASSIS SUBSYSTEM. Detail assessments of the LVS Body and Chassis Subsystem components identified on Table 5.1 are presented in the following paragraphs.

5.3.2.1 Component 1.a- **Cab**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)$_{25}$	Stage 1-4
Possible Cause(s)	Poor Prep/Prime, Abuse, Moisture Trap

Proposed LVSA1 Corrosion Control Measures: E-Coat and Under Coat where appropriate

Assessment:
This component will receive an E-coat and undercoat/rustproofing on the LVSA1. Drain holes, 0.5" diameter, have been added to prevent water build up in the bottom of the structure. OTC has reported difficulty in plug welding HDG portions of the cab weldment to the outer skins. Based on this issue, it is recommended that a zinc-silicate primer followed by application of a zinc phosphate conversion coating be applied prior to the proposed E-coat for the LVSR cab. Zinc-silicate primers are available as water-based, solvent-based and epoxy types, and are well characterized as far as corrosion performance in marine environments (including immersion service) and are relatively inexpensive to apply. At a thickness of about 3 mil, the water based zinc silicate primer costs about 0.39 cents/sq.in. to apply. This coating, when applied in thickness of about 3-to-6 mil, provides corrosion protection equal to 1.7 mil of HDG (Table 5.2).

Recommended LVSR Corrosion Control Measures: Zinc-silicate primer, Phosphate conversion coating, and E-coat and Under Coat where appropriate.

5.3.2.2 Component 1.b- **Fenders**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General, Crevice Corrosion
Stage(s)25	Stage 1-3
Possible Cause(s)	Moisture Trap, Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: Galvanneal E-Coat and Under Coat where appropriate

Assessment:

This component will use galvanneal steel followed by E-coat and rustproof/undercoated in the wheel wells on the LVSA1. This appears to be the appropriate corrosion control option for this application. The minimum thickness of the Galvanneal should be increased over the 0.33 mil proposed for the LVSA1 (0.8 to 1.7 mil) to provide a 10- to 20-year service life. (Reference (3)). The cost of galvanneal is <.0596 cents per square inch @.08-1.7 mil.

Recommended LVSR Corrosion Control Measures: Galvanneal, Zinc Phosphate conversion coating, and E-coat and Under Coat where appropriate.

5.3.2.3 Component 1.c- **Cargo Body and Dropsides**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)[25]	Stage 1-2
Possible Cause(s)	Poor Prep/Prime, Abuse

Proposed LVSA1 Corrosion Control Measures: E-coat and Under Coat where appropriate

Assessment:

This component will be E-coated and rustproof/undercoated on the LVSA1. Since this component takes significant abuse, it is not expected that E-coat, even with a zinc phosphate conversion under-coating, will have a long service life. It is recommended that this component be manufactured using HDG steel (1.7 mil) followed by phosphatizing and E-coat for the LVSR. This approach will increase component costs by about 0.26 cents/sq.in. but should provide long term protection. As a longer term option, this component may be fabricated from protruded fiberglass vinyl ester resin composites. This technology is well within the state of the art. After initial design and evaluation costs are excluded, a composite design should provide both lighter weight and longer term corrosion resistance than coated steel at a competitive price.

Recommended LVSR Corrosion Control Measures: HDGalvanize, Zinc Phosphate conversion coating and E-coat and Under Coat.

5.3.2.4 Component 1.d- **Radiator Grille/Grate Assembly**

LVS Specification:

Material(s)	Steel 11 Gauge
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)$_{25}$	Stage ½
Possible Cause(s)	Poor Prep/Prime, Walking, Abuse

Proposed LVSA1 Corrosion Control Measures: Galvanneal and E-coat

Assessment:

The LVS radiator grille is made of thin gauge carbon steel and is painted. This component suffers from corrosion due to failure of the paint coating. The LVS grate assembly is fabricated from painted 11 gauge steel and suffers from corrosion due to deflection and damage to coating from personnel walking on the grate. The LVSA1 will E-Coat for the radiator grille and will use a 9 gauge galvanneal steel (followed by phosphate conversion coating and paint) for the grate. These improvements appear appropriate and should be effective. The minimum gauge of the zinc coating on the galvanneal should be increased above the 0.33 mil proposed for the fender application, as discussed in 5.3.2.2 above. Other LVSR corrosion control options for these components include a structural polymer matrix composite radiator grille and grate (Reference (8)). The latter technology is being evaluated by Ford Motor Company and can be used in conjunction with the nylon radiator technology evaluated under the USMC 6.2 Corrosion Control Program.

Recommended LVSR Corrosion Control Measures: Application of Galvanneal, Zinc Phosphate conversion coating and E-coat.

5.3.2.5 Component 1.e- **Tool Boxes**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)[25]	Stage 1-3
Possible Cause(s)	Water Trap, Abuse, Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: E-Coat, add drain holes and Under Coat

Assessment:

LVS tool boxes are fabricated from carbon steel and are painted. These components suffer from corrosion due to water accumulation inside the box and abuse that damages the paint coating. LVSA1 will be E-coated and the bottom exterior of the box will be undercoated. Due to the damage from impact of tools, the E-coat is expected to fail and result in corrosion of the steel substrate. Aluminum thermal spray technology has been undergoing evaluation by the USMC and should provide a durable and corrosion resistant tool box (Reference (9)). Breaks in the coating will be protected by the sacrificial corrosion of the aluminum. The cost of application of thermal spray aluminum is about 10.42 cents/sq.in. (including surface preparation, application and sealing) and is somewhat higher than use of galvanized steel (0.26 cent/sq.in.). However, the potential longer term corrosion performance of aluminum is considered to outweigh the cost penalty for this application.

Recommended LVSR Corrosion Control Measures: Aluminum Flame Spray, add drain holes and Under Coat.

5.3.2.6 Component 1.f- **Brackets, Steps, Struts, Supports and Fuel Tank Straps**

LVS Specification:

Material(s)	Steel, SAE1020
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)[25]	Stage ½
Possible Cause(s)	Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: E-coat

Assessment:

These components are fabricated from carbon steel and painted on the LVS. They suffer from general corrosion due to paint coating failure from impact of road debris and wear and abuse during normal operations. E-coat is proposed for corrosion control of the brackets, steps, struts and supports in the LVSA1. Fuel tank straps will be primed and painted and then undercoated between the fender and the fuel tank. It is recommended that the brackets, steps, struts and supports on the LVSR be galvanized and phosphatized prior to E-coat. The galvanizing should be performed after fabrication of these components and should have a minimum thickness in the range of 0.8 to 1.7 mil. For the LVSR fuel tank straps, use of galvanized steel followed by prime and paint should be considered. However, the maximum thickness of zinc coating should be limited to about 0.8 mil to prevent the coating from impairing the ability to attach the straps via their threaded connections. These components should also be painted and undercoated as in the LVSA1. For longer term corrosion protection, fuel tank straps designed using polymer matrix composites (fiber glass) should be considered.

Recommended LVSR Corrosion Control Measures: Galvanize, Zinc Phosphate conversion coating and E-coat and Galvanize prime, paint and under coat between fuel tank and fuel strap

5.3.2.7 Component 1.g- **Tire Hoist**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)[25]	Stage 1-2
Possible Cause(s)	Use, Abuse, Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: E-Coat

Assessment:

This LVS component consists of several parts: a post, a pulley, a tire hoist bracket, and a tire carrier. These parts are made of primed and painted carbon steel and suffer from corrosion due to abuse during use. These parts will be E-coated for the LVSA1. Due to the severe wear and tear associated with this application, it is expected that the E-coat will likely fail and corrosion will be encountered. For the LVSR, it is recommended that the post, tire bracket and tire carrier parts be hot dip galvanized to 0.8 to 1.7 mil followed by zinc phosphate conversion coating and E-coat. The pulley should be manufactured using 17-4 PH stainless steel, hardened to an H1100, or an alloy with the equivalent corrosion and wear resistance. The cost of hot dipped galvanizing is <.0596 cents per square inch @.08-1.7 mil. 17-4 PH stainless steel is approximately $2.62 per pound versus carbon steel at $0.78 per pound.

Recommended LVSR Corrosion Control Measures: Hot Dipped Galvanize, Zinc Phosphate conversion coating and 17-4 PH Stainless Steel pulley and shaft.

5.3.2.8 Component 1.h- **Cab Doors, Hardware**

LVS Specification:

Material(s)	Galvanneal Steel, Steel/Zinc Alloy, Corrosion Resistant Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	Zinc Phosphate conversion coating with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)[25]	Stage 1-2
Possible Cause(s)	Poor Prep/Prime, Moisture Trap

Proposed LVSA1 Corrosion Control Measures: Galvanize, Phosphatize and E-coat

Assessment:
For cab doors and cab door hardware, LVSA1 will utilize a three part corrosion control technology consisting of hot dip galvanneal sheet steel (60-67 gms/sq.m.) followed by a zinc phosphate conversion coating and application of a final E-coat. Galvanneal is a zinc-iron alloy coating that provides better corrosion resistance, weldability and top coat adherence than hot dip galvanized (HDG) coatings. This corrosion control technology is used in the U.S. automotive industry. A zinc rich layer below the E-coat protects the steel in case the E-coat barrier is breached. In this connection, Galvanneal provides more sacrificial protection to steel than HDG. The minimum service life of zinc coatings in tropical marine atmospheres is about 4 years for a coating about 0.4 mil thick. Thus, use of galvanneal steel with a minimum 0.33 mil (60 gms/sq.m.) thick coating and E-coat should provide about 5 years of protection, given that the coating will be breached in service. For longer periods of corrosion resistance, the minimum galvanneal coating thickness should be increased as follows: 0.8 mil for 10 years, and 1.7 mil for 20 years protection. The added thickness of the galvanneal will increase the cost from about 0.05 cents/sq.in. for 0.33 mil to 0.12 cents/sq.in. for 0.8 mil or 0.26 cents/sq.in. for 1.76 mil.

Recommended LVSR Corrosion Control Measures: Application of Galvanneal, Zinc Phosphate conversion coating and E-coat.

5.3.3 ELECTRICAL SUBSYSTEM. Detail assessments of the LVS Electrical Subsystem components identified on Table 5.1 are presented in the following paragraphs.

5.3.3.1 Component 2.a- **Electrical Terminals**

LVS Specification:

Material(s)	Various
Surface Preparation:	None
Corrosion Control Measure(s):	None

Corrosion Description:

Type:	General
Stage(s)$_{25}$	Stage 1-2
Possible Cause(s)	Moisture

Proposed LVSA1 Corrosion Control Measures: Cortec VCI-238

Assessment:
Electrical terminals addressed are on cab circuit breakers and cab switches, low air switches and stop light switches. The LVSA1 will utilize Cortec VCI-238 for coating these terminals. Cortec ElectriCor VCI-238 is an electronic aerosol or liquid spray that forms a dry film that inhibits galvanic or dissimilar metal corrosion encountered in electronic system applications (reference (10)). VCI-238 costs about 0.042 cents /sq. in. and has demonstrated 1512 hours of protection to steel, copper and brass terminals in the ASTM-D-1748 elevated temperature and humidity test. The manufacturer reported that this coating also provided up to 80 hours of performance in the ASTM-B-117 test. Performance of this material in actual marine service could not be verified. An alternative coating that should be suitable for LVSR application is TECTYL 846, Class 1. This solvent cutback, water displacing corrosion prevention compound is government approved, costs less than VCI-238 (0.006 cents/sq.in.) and is under evaluation by CDNSWC (reference (11)). TECTYL 846 has been reported to provide about 1000 hours of protection in ASTM-B-117 testing.

Recommended LVSR Corrosion Control Measures: Application of TECTYL 846 (subject to satisfactory completion of government testing).

5.3.3.2 Component 1.b- **Electronic Control Boxes and Assemblies**

LVS Specification:

Material(s)	Various
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)25	Stage 1-2
Possible Cause(s)	Poor Prep/Prime, Heat

Proposed LVSA1 Corrosion Control Measures: None

Assessment:
Corrosion due to moisture intrusion has been reported as a problem in various LVS actuator box, junction box, and hand control assembly units. No specific corrosion control measures were identified for these components in the LVSA1. However, based on review of corrosion control measures employed for design of such electrical component the following design approaches were identified. All service access panels should be gasketed using polypropylene materials, because they withstand the requirement for repeated opening and closing while maintaining shape/integrity. For lids or openings that are not designed for repeated access, rubber-type gaskets should be employed. All penetrations in these units should be waterproofed. All connectors and plugs that penetrate the sides and bottom of these boxes should be the waterproof type. All wire harnesses entering the boxes should be cord gripped. The cord grip clamps down on the wires at the penetration and prevents ingress of water both along the wires and around the grip device. The wiring harnesses external to the boxes should be designed to include a "drip loop". This permits the water to accumulate locally and fall off of the wires. Desiccant packs should be placed inside of these units to absorb the moisture that penetrates the units. These procedures should be incorporated into the LVSR design. The cost of these measures are dependent upon the severity of the design change required to exclude moisture from the electrical components. At a minimum, the high dollar electronic components must be waterproofed.

Recommended LVSR Corrosion Control Measures: Waterproof enclosures, desiccant packs inside enclosures.

5.3.4 PNEUMATIC AND HYDRAULIC SUBSYSTEMS. Detail assessments of the LVS Pneumatic and Hydraulic Subsystem components identified on Table 5.1 are presented in the following paragraphs.

5.3.4.1 Component 3.a- **Air Reservoir and Brackets**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	Black SAE J10 primer with CARC Top Coat

Corrosion Description:

Type:	General, Crevice Corrosion
Stage(s)$_{25}$	Stage 1-2
Possible Cause(s)	Moisture, Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: Paint to MIL-T-704K

Assessment:

These components are manufactured from carbon steel and were treated with SAE J10 black primer. For the LVSA1, these black primed components will also be painted in accordance with MIL-T704K. It is recommended that the reservoir be galvanized or primed with zinc silicate followed by phosphatizing and E-coat for the LVSR. Zinc silicate primer is 0.39 cents per square inch @3 mil. We were unable to obtain a cost for phosphatizing.

Recommended LVSR Corrosion Control Measures: Application of Galvanize or Zinc silicate primer, Zinc Phosphate conversion coating, E-Coat and Under Coat where appropriate.

5.3.4.2 Component 3.b- **Air Fittings**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	Zinc Flash with MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)25	Stage 1-2
Possible Cause(s)	Moisture Trap, Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: Cortec VCI-386

Assessment:

For the LVSA1, these carbon steel fittings are to be coated to a thickness of 1 to 2 mil using Cortec VCI-386, which is a liquid that provides a composite polymer barrier (reference (12)). ASTM-B-117 tests indicate that VCI-386 coatings of this thickness provide at least 50 hours of protection. It is noted that brass is being required by the USMC for the quick-disconnect air fittings on LVSA1. It recommended that brass fittings conforming to ASTM-B-21-83b be considered for all LVSR air fittings attached to flexible lines. For those fittings attached to steel lines, it is recommended that the use of metallic Sn/30Zn, Zn/10Ni and IVD aluminum coatings and a hybrid chromium-free Dorrlflake coating be considered (references (1), (3), (14), (15) and (16)). These coatings are being used for fittings in the automotive industry and were recently recommended for evaluation (with and without chromates for the metallics) in the USMC corrosion test program. These coatings range in price from about 1.5 to 24 cents/square inch @0.5-1.0 mil.

Recommended LVSR Corrosion Control Measures: Implementation of brass fittings where appropriate and IVD aluminum where appropriate.

5.3.4.3 Component 3.c- **Brake Pneumatic Valve Spring**

LVS Specification:

Material(s)	Various
Surface Preparation:	None
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General, Crevice Corrosion
Stage(s)25	Unknown
Possible Cause(s)	Unknown

Proposed LVSA1 Corrosion Control Measures: E-coat Springs

Assessment:

These carbon steel components are apparently suffering from both general and crevice corrosion in the LVS. The LVSA1 proposes to E-coat these components for improved corrosion resistance. It is recommended that the use of 316 be considered for this application in the LVSR, because 316 stainless has good general and crevice corrosion resistance. Stainless steel is approximately $2.66 per pound versus $0.78 per pound for carbon steel.

Recommended LVSR Corrosion Control Measures: Implementation of 316 Stainless Steel Springs.

5.3.4.4 Component 3.d- **Hydraulic Reservoir and Filter Housing Cap**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General, Crevice Corrosion
Stage(s)$_{25}$	Stage ½
Possible Cause(s)	Moisture Trap

Proposed LVSA1 Corrosion Control Measures: Paint to MIL-T-704K

Assessment:

The reservoir is manufactured from carbon steel and is primed and painted. Corrosion is encountered on the surfaces between the bottom of the reservoir and the fender. This component will be undercoated at the corrosion-susceptible locations for the LVSA1. While the application of undercoat is appropriate, it is recommended that zinc silicate be used for the primer on the reservoir for the LVSR. These primers are relatively low cost and have been found to provide long term protection in marine applications. The filter housing cap is made from carbon steel and is primed and painted on the LVS. This component suffers from general corrosion due to accumulation of water in the cavity that is part of the current design. The LVSA1 will use a coating of Cortec VCI-386 and a topcoat on this component (See 4.1.b. above). VCI-386 is a barrier coating that will likely be damaged during normal operations. Therefore, it is recommended that a zinc silicate primer be used on this component followed by a topcoat. Damage to the zinc silicate coating will not result in corrosion of the steel substrate, because zinc provides sacrificial protection. Several specific zinc silicates are under evaluation by the USMC in their corrosion control programs. A redesign of the cap should be considered to eliminate the recess/cavity in the current design.

Recommended LVSR Corrosion Control Measures: Application of Zinc Silicate primer, Zinc Phosphate conversion coating, E-Coat and under Coat where appropriate, and redesign of the cap.

5.3.4.5 Component 3.e- **Hydraulic Fittings and Fasteners**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	Zinc Oxide with MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)25	Stage 1-2
Possible Cause(s)	Moisture, Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: Cortex VCI-386

Assessment:

For the LVSA1, the carbon steel fittings are to be coated to a thickness of 1 to 2 mil using Cortec VCI-386 which is a liquid that provides a composite polymer barrier (reference (12)). ASTM-B-117 tests indicate that VCI-386 coatings of this thickness provide at least 50 hours of protection. It recommended that 316 stainless steel fittings conforming to ASTM-A-167 Type 316 be considered for all LVSR hydraulic fittings attached to flexible lines. For those fittings attached to steel lines, it is recommended that the use of metallic Sn/30Zn, Zn/10Ni and IVD aluminum coatings and a hybrid chromium free Dorrlflake coating be considered. These coatings are being used for fittings in the automotive industry and were recently recommended for evaluation (with and without chromates for the metallics) in the USMC corrosion test program. As noted above, these coatings range in price from about 1.5 to 24 cents/sq.in.

Recommended LVSR Corrosion Control Measures: Implementation of 316 Stainless Steel where appropriate and IVD aluminum where appropriate.

5.3.4.6 Component 3.f- **Radiators and Transmission and Hydraulic Coolers**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with Black Paint Top Coat

Corrosion Description:

Type:	General
Stage(s)$_{25}$	Stage 1-2
Possible Cause(s)	Moisture, Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: Heresite P-413

Assessment:

These components are made from carbon steel and painted black, and suffer from severe corrosion in the LVS. With regard to the radiators, the LVSA1 will apply a coating of Heresite P-413 to the steel core. Heresite P-413 conforms to MIL-C-18467 and is a phenolic thermosetting resinous coating designed for use on fin tube coils (reference (17)). It provides a barrier against corrosion and provides the thermal conductivity necessary for proper radiator heat expulsion. This coating in thickness of 2 to 3 mil has withstood 3000 hours in ASTM-B-117 testing. With regard to the transmission and hydraulic coolers, the LVSA1 will use a copper tube and fin core with a Heresite P-413 coating. This copper core and fin radiators and associated technology was developed in conjunction with the Copper Development Association and has undergone significant successful tests (reference (18)). It is recommended that performance of the copper core radiator technology proposed for the LVSA1 be monitored, and based on results be considered for both the LVSR transmission and hydraulic coolers, as well as for the LVSR radiator application. In addition, testing of a nylon radiator under the USMC corrosion control program indicates that this technology should also be considered for the LVSR radiator application. Use of the nylon radiator for the transmission and hydraulic coolers on LVSR may not be appropriate because of air flow limitations associated with these applications.

Recommended LVSR Corrosion Control Measures: Implement Copper tube and fin core with Heresite P-413 coating.

5.3.4.7 Component 3.g- **Miscellaneous Fasteners**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	Cad Plated MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)$_{25}$	Stage 1-2
Possible Cause(s)	Use, Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: None

Assessment:

For the fastener applications, the LVS uses cadmium-plated steel. Since cadmium is no longer acceptable due to environmental and safety regulations, alternative fastener coatings and base materials are necessary. With regard to coatings, the same materials identified above for hydraulic fittings, are considered appropriate for fastener applications. However, since the Sn/30Zn and the Zn/10Ni coatings are electrodeposited, their use should be limited to relatively low strength (less than 90 ksi yield strength applications) due to potential for hydrogen embrittlement at higher strength levels. IVD aluminum and Dorrlflake may be used without consideration of fastener yield strength. The cost of IVD aluminum coating is approximately $0.24 per square inch at 0.5 mil.

Recommended LVSR Corrosion Control Measures: Implement IVD aluminum or Dorrlflake.

5.3.5 BATTERY AND POWER TRAIN SUBSYSTEMS. Detail assessments of the LVS Battery and Power train components identified on Table 5.1 are presented in the following paragraphs.

5.3.5.1 Component 4.a- **Battery Box**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	Zinc Oxide with MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)[25]	Stage 1-2
Possible Cause(s)	Moisture, Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: Fiberglass

Assessment:

The LVS battery box is made of carbon steel with a zinc oxide coating. Due to its function and frequent exposure to battery acid, this component suffers severe corrosion. The LVSA1 will use a non-corroding polymer matrix composite material for this component. This appears to be an appropriate measure provided the resin and the design of the box are such to preclude accumulation of and damage from battery acid. It is recommended that the battery box be fabricated using polypropylene matrix composite, since this thermoplastic resin material is reportedly highly resistant to battery acids. Polypropylene has good strength, toughness and is heat resistant. Another option to be considered for the LVSR is application of a thermal spray coating of ethylene methacrylic acid copolymer which was sprayed onto interior and exterior bottom surfaces of a steel battery box on a 939 Series 5-ton truck, which is currently undergoing field testing in the USMC corrosion control program.

Recommended LVSR Corrosion Control Measures: Fiberglass with polypropylene resin.

5.3.5.2 Component 4.b- **Air Cleaner Assembly (Superclone)**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General, Crevice Corrosion
Stage(s)[25]	Stage 1-3
Possible Cause(s)	Moisture Trap

Proposed LVSA1 Corrosion Control Measures: Epoxy primer

Assessment:

This component is made of steel and painted. The location and design of the air cleaner assembly on the LVS results in significant physical abuse producing damage to the coating and accumulation of water inside the assembly. This situation results in both general and crevice corrosion. For the LVSA1, this component is being structurally redesigned to prevent water from entering the assembly. An undefined epoxy primer and a green topcoat will also be applied. While the performance of this redesigned air cleaner assembly should be monitored, the application of zinc silicate versus the unknown epoxy primer should be considered. Another option for this include the use of galvanized steel followed by phosphatizing and E-coat.

Recommended LVSR Corrosion Control Measures: Application of Zinc silicate primer, Zinc Phosphate conversion coating, and E-Coat.

5.3.5.3 Component 4.c- **Propulsion Shafts**

LVS Specification:

Material(s)	Steel
Surface Preparation:	Metal Wash
Corrosion Control Measure(s):	MIL-P-52192 primer with CARC Top Coat

Corrosion Description:

Type:	General
Stage(s)[25]	Stage ½
Possible Cause(s)	Poor Prep/Prime

Proposed LVSA1 Corrosion Control Measures: Prime and Paint

Assessment:

These components include propeller shafts and drive shafts and are made of carbon steel. In the LVS, these components are coated with an unknown primer and suffer from severe surface corrosion. In the LVSA1, the shafts will be painted to MIL-T-704K. The options for this application range from coating with a zinc silicate primers, thermal spray coating/cladding with Inconel 625 to design of a fiber reinforced composite shaft. The cost of implementing these options increases significantly if one moves from zinc silicate to a composite shaft. However, there is a good technology base for each of these options and these should be explored for the LVSR.

Recommended LVSR Corrosion Control Measures: Application of Zinc Silicate Primer and Paint.

5.3.5.4 Component 4.d- **Exhaust Components**

LVS Specification:

Material(s)	Iron Cast, Steel Stainless-Aluminized (Muffler)
Surface Preparation:	None
Corrosion Control Measure(s):	See Above (Muffler)

Corrosion Description:

Type:	General
Stage(s)25	Stage 1-2
Possible Cause(s)	Heat

Proposed LVSA1 Corrosion Control Measures: None

Assessment:

These components on the LVS include the manifold, exhaust elbow, exhaust pipe connector, turbo intake pipe, turbocharger assembly and exhaust outlet. All components are carbon steel except for the manifold which is cast iron. The LVSA1 will continue to use these materials. It is recommend that the following options be considered for the LVSR. For the manifold and turbocharger assembly, apply high temperature coating, such as Ameron PSX 738 (in USMC test program) or Sermagard. Sermagard is a ceramic binder containing dispersed aluminum particles that provides both barrier and sacrificial corrosion protection at temperatures up to 1200 F. For the exhaust elbow, pipe connector and outlet, use aluminized 409 stainless steel. This technology is being evaluated in the USMC corrosion control programs. SermaGuard coating costs $ 0.524 per square inch @ 2.0 mil.

Recommended LVSR Corrosion Control Measures: Implementation of 409 Stainless pipes, aluminized stainless steel muffler, and Ameron PSX 738 for heat guards.

6.0 FINDINGS AND RECOMMENDATIONS

6.1.1 Table 6.1 summarizes the recommended LVSR corrosion control technologies identified from the above assessment. Since marine atmospheric corrosion data was not identified for many of the technologies, recommendations were based on relative performance in ASTM-B-117 testing. Therefore, it is recommended that the following technologies be subjected to marine atmospheric exposures prior to incorporation in the LVSR:

- Tin-Zinc (70%-30%) on steel
- Zinc-Nickel (90%-10%) on steel
- Ion Vapor Deposited aluminum on steel
- Dorrlflake on steel
- Sermagard on steel
- Cortec VCI-238 on steel
- Cortec VCI-386 on steel
- Tectyl-846 on steel
- Zinc Silicate Primer on steel
- E-coat on steel
- Galvanize, Zinc phosphatize, E-coat on steel

Table 6.1-Recommended LVSR Corrosion Control Technologies

Subsystem	Recommended Technology (2)
1. BODY AND CHASSIS	
a. Cab	Zinc silicate, phosphatize, e-coat
b. Fenders	Galvanneal, Phosphatize, E-coat, undercoat
c. Cargo Body and Dropsides	HDGalvanize, Phosphatize, E-coat
d. Radiator Grille/Grate	Galvanneal, Phosphatize, E-coat
e. Tool Boxes	Aluminum Flame Spray
f. Brackets, Steps, Struts, Supports, and Fuel Tank Straps	Galvanize, Phosphatize, E-Coat
g. Tire hoist	HDGalvanize, 17-4 PH Stainless Pulley
h. Cab Doors	Galvanneal, Phosphatize, E-coat
2. Electrical Components	
a. Electrical Terminals	Tectyl 846
b. Electronic control Boxes and Assemblies	Water proof Technology

3. Pneumatic and Hydraulic Components	
a. Air Reservoir and Brackets	HDGalvanize, Phosphatize, E-coat
b. Air Fittings	Brass C36000, IVD Alum and Dorrlflake where appropriate
c. Brake Pneumatic Valve Spring	316 Stainless Steel
d. Hydraulic Reservoir and Filter Housing Cap	Zinc Silicate primer
e. Hydraulic Fittings and Fasteners	316 Stainless Steel, IVD Alum. and Dorrlflake where appropriate
f. Radiators and Transmission and Hydraulic Coolers	Heresite P-413 on copper core
g. Miscellaneous Fasteners	IVD Aluminum Coating
4. Battery and Power Train Components	
a. Battery Box	Polypropylene resin fiberglass
b. Air Cleaner Assembly (Superclone)	Galvanneal, Phosphatize, E-coat
c. Propulsion Shafts	Zinc Silicate primer
d. Exhaust Components	409 Stainless steel, Aluminized Stainless

6.1.2 The following technologies have demonstrated marine atmospheric corrosion performance and should be considered for both the LVS ATD and the LVSR. Evaluation in the LVS ATD will provide added assurance of effective performance in an LVS "system" context.

- Plastic Radiator
- 316 stainless steel hydraulic fittings
- Brass Pneumatic fittings
- Fiberglass battery box
- Aluminum flame sprayed tool boxes
- Undercoat/rustproof of appropriate areas
- Composite Cargo Body

7.0 PERFORMANCE-BASED SPECIFICATIONS

7.1 Table 7.1 presents criteria for evaluating the performance of the recommended LVSR corrosion control technologies identified in this investigation. The criteria represent the minimum performance that should be expected from the recommended technology or any proposed alternative. It is noted that marine atmospheric corrosion performance was not available for several of the recommended technologies. Therefore, ASTM-B-117 performance was specified. Results of marine atmosphere exposures should be obtained and used for performance criteria, since the performance in ASTM-B-117 tests do not always correlate with actual marine atmosphere exposures. In addition, as results of ongoing government marine exposures and field tests (i.e. aluminized 409 stainless steel and fiberglass battery boxes in the LVSA1) become available, these criteria should be updated. Criteria are not presented for the waterproofing of electronic enclosures because no specific test results were identified. Testing of electronic enclosures waterproofed according to the guidelines presented in paragraph 5.3 is recommended.

Table 7.1- Performance Based Specifications for the LVSR Subsystems and Components

Subsystem	Recommended Technology (1)	Performance Criteria (2)
1. BODY AND CHASSIS		
a. Cab	Zinc silicate, phosphatize, e-coat	At least 6500 hr @3 mils in ASTM B117
b. Fenders	Galvanneal, Phosphatize, E-coat, undercoat	Corrosion rate < or =0.2 mil/yr in Marine Atmosphere Exposure
c. Cargo Body and Dropsides	HDGalvanize, Phosphatize, E-coat	Corrosion rate < or =0.2 mil/yr in Marine Atmosphere Exposure
d. Radiator Grille/Grate	Galvanneal, Phosphatize, E-coat	Corrosion rate < or =0.2 mil/yr in Marine Atmosphere Exposure
e. Tool Boxes	Aluminum Flame Spray	Corrosion rate < or =0.001 mil/yr in Marine Atmosphere Exposure
f. Brackets, Steps, Struts, Supports, and Fuel Tank Straps	Galvanize, Phosphatize, E-Coat	Corrosion rate < or =0.2 mil/yr in Marine Atmosphere Exposure
g. Tire hoist	HDGalvanize, 17-4 PH Stainless Pulley	Corrosion rate < or =0.2 mil/yr in Marine Atmosphere Exposure
h. Cab Doors	Galvanneal, Phosphatize, E-coat	Corrosion rate < or =0.2 mil/yr in Marine Atmosphere Exposure
2. Electrical Components		
a. Electrical Terminals	Tectyl 846	At least 1000 hr @1 mils in ASTM B117
b. Electronic control Boxes and Assemblies	Water proof Technology	
3. Pneumatic and Hydraulic components		
a. Air Reservoir and Brackets	HDGalvanize, Phosphatize, E-coat	Corrosion rate < or =0.001 mil/yr in Marine Atmosphere Exposure
b. Air Fittings	Brass C36000 (Half Hard free cutting)	Corrosion rate < or =0.056 mil/yr in Marine Atmosphere Exposure
c. Brake Pneumatic valve Spring	316 Stainless Steel	Corrosion rate < or =0.001 mil/yr in Marine Atmosphere Exposure
d. Hydraulic Reservoir and filter Housing Cap	Zinc Silicate primer	At least 6500 hr @3 mils in ASTM B117
e. Hydraulic Fittings and Fasteners	316 Stainless Steel	Corrosion rate < or =0.001 mil/yr in Marine Atmosphere Exposure
f. Radiators and Transmission and Hydraulic Coolers	Heresite P-413 on copper core	At least 3000 hr @2-3 mils in ASTM B117
g. Miscellaneous Fasteners	IVD Alumnium Coating	At least 336 hrs @0.5 mils in ASTM B117
4. Battery and Power Train Components		
a. Battery Box	Polypropylene resin fiberglass	
b. Air Cleaner Assembly (Superclone)	Galvanneal, Phosphatize, E-coat	Corrosion rate < or =0.2 mil/yr in Marine Atmosphere Exposure
c. Propulsion Shafts	Zinc Silicate primer	At least 6500 hr @3 mils in ASTM B117
d. Exhaust Components	409 Stainless steel, Aluminized Stainless	

Note (1): See Table 5.2 for description of technologies

(2): Criteria for evaluating proposed options to the Recommended Technology

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APPENDIX A
CORROSION-PRONE LVS COMPONENTS

Appendix A - Corrosion-Prone LVS Components

Part	NSN	Part Number / Cage Code	Cost from Haystack for LVS (not LVSA1)	MK 48	MK 14	MK 15	MK 16	MK 17	MK 18
Propeller Shaft, Wit (Trans to TC)	2520012197596	913449/51205	$928.70	x					
Propeller Shaft, Wit (TC to Nose Box)	2520012197883	912252-3927/51205	$749.31	x					
Propeller Shaft (#1 to #2 Axle)	2520012201299	1430210/51205	$371.53	x					
Shaft Assembly	3040012180009	6-60-311-0518/72447	$266.85	x					
Shaft Drive, Steering Pump	2520012430083	909701-1/95019	$180.09	x					
Shaft, Propeller Wit (#3 axle to pillow block bearing)	2520012538691	912252-6015/51205	$513.06				x		
Propeller Shaft, Wit (Cntr Bearing to #3 Axle)	2520012672096	912252-4319/51205	$637.82		x	x		x	x
Propeller Shaft (#3 to #4 Axle)	2520012343611	913450-0901/51205	$537.80		x	x		x	x
Propeller Shaft, Wit (Cntr Bearing Assembly)	2520012672097	913649-3422/51205	$547.33		x	x		x	x
Air Hose Anchor Fittings - D - Artic - Joint	4730008815536	411-125/01276	$5.55						
Air Hose Anchor Fittings - C - Artic - Joint	4730005682258	411-105/01276	$2.19						
Air Hose Anchor Fittings	4730010817467 4730004070571 4730009191803	EE102662/45152 EE62452/45152 1220FX/45152	$7.12 $15.56 $3.57	x					
Air Hose Anchor Fittings - A - Artic - Joint	4730010657552	411-65/01276	$1.69						
Air Hose Anchor Fittings - B - Artic - Joint	4730006847441	411-85/01276	$2.62						
Coupling Half, Quick Disconnect - Fitting Air	4730006081044	FD45-1003-08-10/01276	$35.29	x					
Quick Disconnect Air Couplings	4370012175728 4370012182500	FD45-1045-06-06/01276 FD45-1046-06-06/01276	$13.39 $5.79	x	x	x	x	x	x
Coupling Half, Quick Disconnect - Female	4730008402133	FD45-1003-06-06/01276	$5.76	x					

Appendix A - Corrosion-Prone LVS Components

Part	NSN	Part Number / Cage Code	Cost from Haystack for LVS (not LVSA1)	MK 48	MK 14	MK 15	MK 16	MK 17	MK 18
Coupling Half, Quick Disconnect - Male	4730000617635 4730006209306 4730000617635	FD45-1002-08-10/01276 FD45-1002-06-06/01276 FD45-1003-08-10/01276	$5.04 $4.83 $5.04	x					
Chamber Assembly - Front Brake	2530012480340	215-3276-T-20/78500	$259.16	x					
Reservoir, Air	2530011816770	D-1094/84290	$52.01	x					
Reservoir, Air	2530003778779	217321/06853	$36.87		x	x	x	x	x
Bracket, Reservoir, Air	5340011794612	281554/06853	$27.86	x					
Bracket, Reservoir, Air	5340004962587	205093/06853	$12.64		x	x	x	x	x
Valve, Brake Pneumatic	2530012600339	1451400/45152	$117.10	x					
Deck Assembly	2510012419401	1438000W/45152	$385.48				x		
Bracket, XMSN Oil Filter	5340012150151	1381390W/45152	Not Found	x					
Strap, Mounting (Fuel Tank Strap)	5340012098817	OS3982/98624	$41.14	x					
Body Cargo Truck (Cargo, Body 20 Foot)	2510012414320	1429710/45152	$10,154.57		x				
Body Cargo Truck (Wrecker, 11 Foot)	2510013055668	1428890/45152	Not Listed			x			
Head and Tailgate Assembly	2510012367258	A154133/72241	$287.06					x	
Body Cargo Trailer (Weldment Body)	2510012166883	A154094/77241	$7,324.81					x	
Troop Seats/Dropside	2510012166880 2510012166881 2510012166882	A155297/72241 A155378/72241 A154109/45152	$395.98 $470.71 $325.80					x	
Bracket, Marker Light	5340012372078	1371780/45152	$59.51	x					
Bracket, Step	2540011513844	1325890/45152	$24.11	x					

Appendix A - Corrosion-Prone LVS Components

Part	NSN	Part Number / Cage Code	Cost from Haystack for LVS (not LVSA1)	MK 48	MK 14	MK 15	MK 16	MK 17	MK 18
Cab Assembly, Sheet MetaL	2510012334842	123771RW/45152	$6,260.79	x					
Frame Door LH,RH	2510012331737 2510012338085	1309830W/45152 1309820W/45152	$514.11 $493.32	x					
Inner Skin LH Assembly, Cab Door	2510011560557	1310380W/45152	$587.32	x					
Inspection Cover	5340011586318	126895B/45152	$6.62	x					
Inner Skin RH Assembly, Cab Door	2510011555835	1310370W/45152	$41.97	x					
Rod, Outer Handle	5306011565201	1320730/45152	$8.42	x					
Spring (Door Latch)	5360011554565	1321570/45152	$4.46	x					
Fender - RH	2510012662120	1493830W/45152	$244.57	x					
Angle Bracket (Angle, Wheel Chock)	5340012139992	141120/45152	$95.30	x					
Strut Support (Cab Step)	5340012406044	125769C/45152	$56.96	x					
Step, Side Fender	2540012076084	125734CW/45152	$121.63	x					
Fender - LH	2510012547939	1493840W/45152	$233.42	x					
Support, Fender RH, LH	5340012436576 5340012406041	125636CW/45152 1258840CW/45152	$31.74 $41.02	x					
Strip Retainer Fender	5365012142266	128127B/45152	$15.20	x					
Strip Retainer Fender	5365012143529	1448490/45152	$15.20	x					
Strip Retainer Cab	5365012142267	128129B/45152	$15.20	x					
Battery Box	2510012086581	124374D/45152	$206.23	x					

Appendix A - Corrosion-Prone LVS Components

Part	NSN	Part Number / Cage Code	Cost from Haystack for LVS (not LVSA1)	MK 48	MK 14	MK 15	MK 16	MK 17	MK 18
Tool Box	2540012378320	1377260W/45152	$306.95			x		x	
Tool Box	2540012643824 5140012174387	1475560/45152 1338980W/45152	$331.64 $100.00		x				
Tool Box	2540012434816 2540012434817	1334250W/45152 1338980W/45152	$410.86 $379.72				x		
Tire Hoist Assembly	25100012081400	126747RU/45152	$1,246.30	x					
Fitting, Coupling (Hydr. Quick Disconnect)	4730000617635	FD45-1003-08-10/01267	$5.04						
Fitting, Air, Air (Hydr. Quick Disconnect)	4730006081044	FD45-1003-12-12/01770	$35.29						
Fitting, Coupling (Hydr. Quick Disconnect)	4730008552125	FD45-1003-16-16/01276	$27.04						
Fitting Coupling (Hydr. Quick Disconnect)	4730008833790	FD45-1002-16-16/01276	$11.49						
Coupling, Male (Hydr. Quick Disconnect)	4730000617635	FD45-1002-08-10/01276	$5.04						
Fitting, Coupling, Male (Hydr Quick Disconnect)	4730011924450	FD45-1002-12-12/01276	Not Found						
Filter, Assembly (Hydraulic)	2940012423031	HH2124UNSAGY108/06816	$705.37	x					
Hydraulic Reservoir	2590012423110	1451670W/45152	$1,335.82	x					
Valve, Hydraulic (8-ball)	4810011827225	986552/51205	Not Found	x					
Radiator, Engine Cool	4420011816743	122626D/45152	$2,254.32	x					
Grate, Radiator Grille	2510012072491	1340860W/45152	$394.26	x					
Hydraulic Oil Cooler (Cooler, Fluid, Trans)	2520012427970	837/17285	$715.58						
Cooler, Oil, Transmission	2935011830731	699/17285	$734.64	x					

Appendix A - Corrosion-Prone LVS Components

Part	NSN	Part Number / Cage Code	Cost from Haystack for LVS (not LVSA1)	MK 48	MK 14	MK 15	MK 16	MK 17	MK 18
Grille (Skid Plate)	2510012427887	1342860/45152	$258.46	x					
Grille, Radiator	2510012072519	127885RW/45152	$417.86	x					
Switch, Low Air (Treadle Valve)	5930011489149	51745-4106/81958	$4.99	x					
Switch, Stop Light (Treadle Valve)	5930010764114	286416/06853	$29.33	x					
Turbo Charger Assembly	2950011674280	8923340/72582	$883.00	x					
Connector, Exhaust Pipe	2990012433586 2990012433575 2990012434908	BJ507/01652 1498040W/45152 1310440/45152	$86.26 $125.81 $55.65						
Elbow Exhaust	2990012434908	1310440/45152	$55.65	x					
Elbow, Exhaust Outlet	2990012131688	124365B/45152	$45.84	x					
Manifold, Exhaust, LH, RH	2815010953250 2815010944931	51296113/45152 5129643/45152	$122.05	x					
Muffler Exhaust	2990011329173	MAM10-0417/45152	$110.98	x					
Pipe, Exhaust	2990012433575	1498040W/45152	$125.81	x					
Tube, Left Bank (Exhaust Cross Over Pipe)	2990012057879	5146775/72582	$44.73	x					
Turbo Intake Pipe/High Temp Manifolds	2990012059449	5146528/72582	$175.79	x					
Air Cleaner Assembly	2940012064611	C-70044/21585	$587.15	x					
Engine Crossover Pipe	No NSN Listed		Not Found	x					
Guard, Muffler Exhaust	2990012131679	1307770W/45152	$216.78	x					
Flange	2530012068805	F1021TIE/64441	$162.05	x					

Appendix A - Corrosion-Prone LVS Components

Part	NSN	Part Number / Cage Code	Cost from Haystack for LVS (not LVSA1)	MK 48	MK 14	MK 15	MK 16	MK 17	MK 18
Plate, Flange Clamp	5340013137961	1443020/64441	$14.73	x	x	x	x	x	x
Actuator, Electro-Mechanical, Rotary	4810012756244	308-25-3510/35863	$7,773.26					x	
Junction Box Assembly	5925012342722 6110012342722	S000-25-2883/35683	$347.30			x		x	
Cover, w/seal	5340012454157	308-25-3621/35683	$2917.20?			x			
Actuator, Electro-Mechanical, Rotary	3010012205829	308-25-3513/35683	$7,773.26			x			
Hand Control Assembly, 6 Function (Electrical Remote Control)	2590012197817	308-25-3515/35683	$2,544.54			x			
Hand Control Assembly, 4 Function (Electrical Remote Control)	3040012430974	308-25-3512/35683	$2,442.76					x	